SMRP Best Practices

5th Edition

MAINTENANCE & RELIABILITY BODY OF KNOWLEDGE

For more information about SMRP or the Best Practices Committee, please go to **www.smrp.org**.

SMRP
Society for Maintenance & Reliability Professionals

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METRICS INTRODUCTION

When a company promises and delivers its best business plans, there is a good chance that customer satisfaction and retention will be high. Paving the road to success depends on companies being well-informed about their own business and understanding and implementing an appropriate business plan. Companies can achieve that knowledge by developing and utilizing effective metrics.

Metrics are used to drive improvements and help businesses focus their people and resources on what's important. The range of metrics companies can employ vary from those that are mandatory to those that track increase in efficiency, reductions in complaints, greater profits and better savings. Metrics indicate the priorities of the company and provide a window on performance. Ultimately, metrics will help tell the organization where it has been, where it is heading, whether something is going wrong and when the organization reaches its target. Metrics should encourage the right behavior, should be difficult to manipulate and easily reported (taken from section 3.7 titled "Maintenance Assessment and Improvement" of Ramesh Gulati's book *Maintenance and Reliability Best Practices*).

The Society for Maintenance & Reliability Professionals (SMRP) has developed a core set of metrics for the five pillars of maintenance and reliability. We have overlaid these metrics from the five pillars to align with strategic, operating and effectiveness (tactical) classifications. Please use this as a guide when selecting the "right" metrics for your organization.

Pillar 1
Business & Management

MAINTENANCE & RELIABILITY BODY OF KNOWLEDGE

SMRP
Society for Maintenance & Reliability Professionals

BUSINESS & MANAGEMENT METRIC

1.1 RATIO OF REPLACEMENT ASSET VALUE (RAV) TO CRAFT-WAGE HEADCOUNT

Published on April 16, 2009

DEFINITION

This metric is the replacement asset value (RAV) of the assets being maintained at the plant divided by the craft-wage employee headcount. The result is expressed as a ratio in dollars per craft-wage employee.

OBJECTIVES

This metric allows organizations to compare the ratio of craft-wage personnel on a site with other sites, as well as to benchmark data. The RAV is used in the numerator to normalize the measurement, given that different plants vary in size and replacement value. The metric can be used to determine the standing of a plant relative to best-in-class plants which have high asset utilization and equipment reliability and generally have lower maintenance craft-wage cost.

FORMULA

Ratio of Replacement Asset Value ($) to Craft-Wage Head Count = RAV ($) / Craft-Wage Headcount

COMPONENT DEFINITIONS

Craft-Wage Headcount
The number of maintenance personnel responsible for executing work assignments pertaining to maintenance activities. Includes the number of contractors' personnel who are used to supplement routine maintenance. The headcount is measured in full-time equivalents (FTE).

Estimated Replacement Asset Value (ERV)
Also referred to as Replacement Asset Value (RAV), it is the dollar value that would be required to replace the production capability of the present assets in the plant. Includes production/process equipment, as well as utilities, facilities and related assets. Does not use the insured value or depreciated value of the assets. Includes the replacement value of buildings

and grounds if these assets are included in maintenance expenditures. Does not include the value of real estate, only improvements.

Replacement Asset Value (RAV)
Also referred to as estimated replacement value (ERV), it is the dollar value that would be required to replace the production capability of the present assets in the plant. Includes production/process equipment as well as utilities, facilities and related assets. Also includes the replacement value of buildings and grounds if these assets are included in maintenance expenditures. Does not include the insured value or depreciated value of the assets, nor does it include the value of real estate, only improvements.

QUALIFICATIONS

1. Time basis: Yearly
2. This metric is used by maintenance managers to measure the effectiveness of their craft-wage workforce.
3. This metric can be calculated and used to compare a process, a department or an entire facility.
4. Contractors that are employed as part of capital projects or upgrade work should not be included.
5. Contract employees who support the regular maintenance workforce and perform maintenance on a site should be included.
6. If contract costs for painting, plumbing, carpentry and similar activities are included as part of the RAV, this contract headcount should be included in the denominator.
7. A full-time equivalent should be normalized at 40 hours per week.
8. For facilities using total productive maintenance (TPM), maintenance performed by operators should be included.

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SAMPLE CALCULATION

For a given facility, the replacement asset value ($) is $624,500,000 and the craft-wage headcount for maintenance employees is 150.

The Ratio of Replacement Asset Value ($) to Craft-Wage Headcount = RAV ($) / Craft-Wage Headcount

The Ratio of Replacement Asset Value ($) to Craft-Wage Headcount = $624,500,000 / 150 maintenance employees

The Ratio of Replacement Asset Value ($) to Craft-Wage Headcount = $4,160,000 per maintenance employee

HARMONIZATION

This metric is not harmonized.

REFERENCES

None

BUSINESS & MANAGEMENT METRIC

1.3 MAINTENANCE UNIT COST

Published on April 16, 2009
Revised on September 26, 2012

DEFINITION

This metric is the measure of the total maintenance cost required for an asset or facility to generate a unit of production.

OBJECTIVES

This metrics allows organizations to quantify the total maintenance cost to produce a standard unit of production over a specified time period (e.g., monthly, quarterly, annually, etc.). It provides a period over period trend of maintenance cost per unit produced. This measure can be applied to a specific asset, a group of assets within a facility, across an entire facility or across multiple facilities.

FORMULA

Maintenance Unit Cost = Total Maintenance Cost / Standard Units Produced

COMPONENT DEFINITIONS

Standard Units Produces
A typical quantity produced as output. The output has acceptable quality and consistent means to quantify. Examples include: gallons, liters, pounds, kilograms or other standard units of measures.

Total Maintenance Cost
The total expenditures for maintenance labor, including maintenance performed by operators such as total productive maintenance (TPM), materials, contractors, services and resources. Includes all maintenance expenses for outages, shutdowns or turnarounds, as well as normal operating times. Also includes capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include capital expenditures for plant expansions or improvements.

QUALIFICATIONS

1. Time Basis: Annually - If a shorter interval is used, it should include a weighted portion of planned outages or turnarounds.
2. This metric is used by maintenance, operations, finance or other departments to evaluate and benchmark maintenance cost for production units within a plant, across multiple plants or against the industry
3. To obtain data necessary for this measure, total maintenance cost includes all costs associated with maintaining the capacity to produce over a specified time period.
4. Standardized units are industry-typical measures that enable valid comparisons across similar businesses. These are the gross standard units, disregarding any first pass quality losses and must be the same for comparison purposes.
5. Output variances, such as production curtailments due to business demand or operational issues unrelated to maintenance, will negatively impact this measure.
6. Measuring maintenance cost on a specific asset within a facility will require appropriate accounting of distributed costs (e.g., infrastructure costs allocated to the asset from the site). A percentage of building and grounds costs directly associated with the preservation of the production asset should be applied to the asset.
7. The unit maintenance cost on different products can vary significantly even though they have the same units of measure. Exercise care when comparing different products or processes.

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SAMPLE CALCULATION

The total maintenance cost for the year was $2,585,000. The total output from the manufacturing site in that same year was 12,227,500 kg.

Maintenance Unit Cost = Total Maintenance Cost / Standard Units Produced

Maintenance Unit Cost = $2,585,000 / 12,227,500 kg

Maintenance Unit Cost = $0.21 per kg

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee was unable to find any target ranges, minimum/maximum values, benchmarks or other references for target values for this metric. SMRP will update this metric as appropriate should future work help establish targets for this metric. While no target values are currently available, SMRP encourages plants to use this metric to help manage maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric and its supporting definitions are similar to the indicator E3 in standard EN 15341.

Note 1: The difference between the SMRP metrics and indicator E3 is that EN 15341 has a broader definition of total maintenance cost and includes depreciation of maintenance owned equipment and facilities (e.g., office, workshop and warehouse).

Note 2: The EN 15341 definition of the denominator, quantity of output is, "Production or service quantity issued by an asset/item (tons, liters, etc.)," expanding the definition to more than a physical product. The SMRP component definition for the denominator, standard units produced includes other standard unit of measures. This makes the two component definitions identical.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the E3 indicator.

Additional information is available in the document *Global Maintenance and Reliability Indicators*, which is located in the SMRP Library.

REFERENCES

This metric is approved by consensus of SMRP Best Practice Committee.

BUSINESS & MANAGEMENT METRIC

1.4 STOCKED MAINTENANCE, REPAIR AND OPERATING MATERIALS (MRO) INVENTORY VALUE AS A PERCENT OF REPLACEMENT ASSET VALUE (RAV)

Published on April 16, 2009

DEFINITION

This metric is the value of maintenance, repair and operating materials (MRO) and spare parts stocked onsite to support maintenance, divided by the replacement asset value (RAV) of the assets being maintained at the plant, expressed as a percentage.

OBJECTIVES

This metric enables comparisons of the value of stocked maintenance inventory onsite with other plants of varying size and value, as well as comparison to other benchmarks. The RAV is used in the denominator to normalize the measurement, given that different plants vary in size and value.

FORMULA

Stocked MRO Inventory Value per RAV (%) =
[Stocked MRO Value ($) × 100] / Replacement Asset Value ($)

COMPONENT DEFINITIONS

Estimated Replacement Value (ERV)

Also referred to as Replacement Asset Value (RAV), it is the dollar value that would be required to replace the production capability of the present assets in the plant. Includes production/process equipment, as well as utilities, facilities and related assets. Does not use the insured value or depreciated value of the assets. Includes the replacement value of buildings and grounds if these assets are included in maintenance expenditures. Does not include the value of real estate, only improvements.

MRO (Maintenance, Repair and Operating Materials)
An acronym to describe maintenance, repair and operating materials (MRO) and spare parts.

Replacement Asset Value (RAV)
Also referred to as estimated replacement value (ERV), it is the dollar value that would be required to replace the production capability of the present assets in the plant. Includes production/process equipment as well as utilities, facilities and related assets. Also includes the replacement value of buildings and grounds if these assets are included in maintenance expenditures. Does not include the insured value or depreciated value of the assets, nor does it include the value of real estate, only improvements.

Stocked Maintenance, Repair and Operating Materials (MRO) Inventory Value
The current book value of maintenance, repair and operating (MRO) supplies in stock, including consignment and vendor-managed inventory. Stocked MRO inventory value includes the value of MRO materials in all storage locations including satellite and/or remote storeroom locations, whether or not that material is included in inventory asset accounts or an allocated portion of pooled spares. Estimates the value of unofficial stores in the plant, even if they are not under the control of the storeroom or are not on the books. Includes estimated value for stocked material that may be in stock at zero value because of various computerized maintenance management systems (CMMS) and/or accounting idiosyncrasies, etc. Does not include raw material, finished goods, packaging materials and related materials.

The monetary cost of an individual storeroom item is calculated as: Monetary Cost of Individual Storeroom Item = Quantity on Hand × Individual Item Cost

The aggregated cost of all storeroom items is calculated as: ∑N (Quantity on Hand × Individual Item Cost)i.

QUALIFICATIONS

1. Time basis: Annually and/or quarterly
2. This metric is typically used by corporate managers to compare plants. It is also used by plant managers, maintenance managers, materials managers, procurement managers, operations managers, reliability managers and vice presidents.
3. It can be used to determine the standing of a plant in a four-quartile measurement system, as in most industries. Best-in-class plants with high asset utilization and high equipment reliability have less stocked inventory value because they have a more predictable need for materials.

4. Do not rely on this metric alone, since lower stocked inventory value does not necessarily equate to best-in-class. Instead, balance this metric with stock-outs (which should be low) and other indicators of the service level of the stocked inventory.

SAMPLE CALCULATION

If stocked MRO inventory value is $3,000,000, and the replacement asset value (RAV) is $100,000,000, then the stocked MRO inventory value as a percent of RAV would be:

Stocked MRO Inventory Value per RAV (%) =
[Stocked MRO Value ($) × 100] / Replacement Asset Value ($)

Stocked MRO Inventory Value per RAV (%) =
($3,000,000 × 100) / $100,000,000

Stocked MRO Inventory Value per RAV (%) = 3%

BEST-IN-CLASS TARGET VALUE

Generally less than 1.5%; top quartile range is 0.3% to 1.5%, varying by industry

CAUTIONS

Top quartile target is reasonable only if maintenance practices are advanced and mature. The target should be higher if maintenance practices are not advanced and not mature. For example, a third quartile plant with third quartile practices will have to maintain a third quartile inventory level (higher compliment of spare parts) to account for the uncertainty and unpredictable need for materials. Reducing inventory levels in a less advanced and less mature maintenance practice will result in severe stock-outs and consequential extended downtime.

Regarding the variation by industry, an abundance of data suggests that lighter, less complex industries (e.g., non-industrial facilities) tend to require less stocked inventory than heavier industries (e.g., mining), although the differences are quite small in the top quartile. The range shown above describes the lowest industry's top-of-the-top quartile target (0.3%) and the highest industry's bottom-of-the-top quartile target (1.5%). Targeting 1.5% may or may not be appropriate for a particular facility. Consultation with experts is advised to establish the appropriate target for the facility.

HARMONIZATION

This metric and its supporting definitions are similar to the indicator E7 in standard EN15341.

Note 1: Both indicators exclude depreciation cost for strategic parts

Note 2: SMRP metrics include operating materials. The EN 15341 definition only includes maintenance materials. This can give a higher value compared to the EN15341 indicator.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the E7 indicator.

Additional information is provided in the document *Global Maintenance and Reliability Indicators*, available in the SMRP Library.

REFERENCES

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BUSINESS & MANAGEMENT METRIC

1.5 TOTAL MAINTENANCE COST AS A PERCENT OF REPLACEMENT ASSET VALUE (RAV)

Published on April 16, 2009

DEFINITION

This metric is the amount of money spent annually maintaining assets, divided by the replacement asset value (RAV) of the assets being maintained, expressed as a percentage.

OBJECTIVES

This metric allows comparisons of the expenditures for maintenance with other plants of varying size and value, as well as comparisons to benchmarks. The RAV is used in the denominator to normalize the measurement given that plants vary in size and value.

FORMULA

Total Maintenance Cost per RAV (%) =
[Total Maintenance Cost ($) × 100] / Replacement Asset Value ($)

COMPONENT DEFINITIONS

Annual Maintenance Cost

Annual maintenance cost is the annual expenditures for maintenance labor, including maintenance performed by operators (e.g., total productive maintenance (TPM), materials, contractors, services and resources). Includes all maintenance expenses for outages, shutdowns or turnarounds, as well as normal operating times. Includes capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include capital expenditures for plant expansions or improvements. When calculating, ensure maintenance expenses included are for the assets included in the replacement asset value (RAV) in the denominator.

Estimated Replacement Asset Value (ERV)

Also referred to as Replacement Asset Value (RAV), it is the dollar value that would be required to replace the production capability of the present assets in the plant. Includes production/process equipment, as well as utilities, facilities and related assets. Does not use the insured value or depreciated value of the assets. Includes the replacement value of buildings and grounds if these assets are included in maintenance expenditures. Does not include the value of real estate, only improvements.

Replacement Asset Value (RAV)
Also referred to as estimated replacement value (ERV), it is the dollar value that would be required to replace the production capability of the present assets in the plant. Includes production/process equipment as well as utilities, facilities and related assets. Also includes the replacement value of buildings and grounds if these assets are included in maintenance expenditures. Does not include the insured value or depreciated value of the assets, nor does it include the value of real estate, only improvements.

Total Maintenance Cost
The total expenditures for maintenance labor, including maintenance performed by operators such as total productive maintenance (TPM), materials, contractors, services and resources. Includes all maintenance expenses for outages, shutdowns or turnarounds, as well as normal operating times. Also includes capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include capital expenditures for plant expansions or improvements.

QUALIFICATIONS

1. Time basis: Annually
2. This metric is typically used by corporate managers to compare plants. It is also used by plant managers, maintenance managers, operations managers, reliability managers and vice presidents.
3. It can be used to determine the standing of plant in a four-quartile measurement system, as in most industries. Best-in-class plants with high asset utilization and high equipment reliability spend less maintaining their assets.
4. SMRP suggests not relying on this metric alone since lower maintenance cost does not necessarily equate to best-in-class.

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SAMPLE CALCULATION

If total maintenance cost is $3,000,000 annually and the replacement asset value for the assets is $100,000,000, then the total maintenance cost as a percent of replacement asset value would be:

Total Maintenance Cost As a Percent of RAV =
[Annual Maintenance Cost ($) × 100] / Replacement Asset Value

Total Maintenance Cost As a Percent of RAV = ($3,000,000 × 100) / $100,000,000

Total Maintenance Cost As a Percent of RAV = 3%

BEST- IN- CLASS TARGET VALUE

Generally less than 3%; top quartile range is 0.7% to 3.6%, varying by industry

CAUTIONS

Top quartile target is reasonable only if maintenance practices are advanced and mature. The target should be higher if maintenance practices are not advanced and not mature. For example, a third quartile plant with third quartile practices will have to spend at a third quartile level (more maintenance dollars) in order to maintain reasonable reliability and avoid asset degradation.

Regarding the variation by industry, an abundance of data suggests that lighter, less complex industries (non-industrial facilities, for example) tend to spend less than heavier industries (mining, for example), although the differences are quite small in the top quartile. The range shown above describes the lowest industry's top-of-the-top quartile target (0.7%) and the highest industry's bottom-of-the-top quartile target. Targeting 1.5% may or may not be appropriate for a particular facility. Consultation with experts is advised to establish the appropriate target for the facility.

HARMONIZATION

This metric and its supporting definitions are similar to EN 15341 Indicator E3.

Note 1: This metrics and EN 15341 are different in that EN 15341 has a broader definition and includes depreciation of maintenance owned equipment and facilities in total maintenance cost (office, workshop and warehouse).

Note 2: The SMRP term replacement asset value is equal to the EN 15341 term asset replacement value.

Note 3: The SMRP metric is calculated on an annual basis. EN 15341 is undefined in terms of time.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the E1 indicator. Additional information is available in the document *Global Maintenance and Reliability Indicators*, available in the SMRP Library.

REFERENCES

AT Kearny. (n.d.) Published benchmarks for the chemical processing industry. Chicago, IL

Gulati, R. (2009). *Maintenance and reliability best practices*. South Norwalk, CT: Industrial Press, Inc.

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Pillar 2
Manufacturing Process Reliability

MAINTENANCE & RELIABILITY BODY OF KNOWLEDGE

Society for Maintenance & Reliability Professionals

MANUFACTURING PROCESS RELIABILITY METRIC

2.1.1 OVERALL EQUIPMENT EFFECTIVENESS (OEE)

Published on April 16, 2009
Revised on August 3, 2016

DEFINITION

This metric is a measure of equipment or asset performance based on actual availability, performance efficiency and quality of product or output when the asset is scheduled to operate. Overall equipment effectiveness (OEE) is typically expressed as a percentage.

OBJECTIVES

This metric identifies and categorizes major losses or reasons for poor asset performance. It provides the basis for setting improvement priorities and beginning root cause analysis. OEE also fosters cooperation and collaboration between operations, maintenance and equipment engineering to identify and reduce and/or eliminate the major causes of poor performance. Maintenance alone cannot improve OEE.

FORMULA

Overall Equipment Effectiveness Formula
Overall Equipment Effectiveness (%) =
Availability (%) × Performance Efficiency (%) × Quality Rate (%)

Availability Formula
Availability (%) = [Uptime (hrs) × 100] / [Total Available Time (hrs) – Idle Time (hrs)]

Uptime Formula
Uptime (hrs) = Total Available Time (hrs) – [Idle Time (hrs) + Total Downtime (hrs)]

Total Downtime Formula
Total Downtime (hrs) = Scheduled Downtime (hrs) + Unscheduled Downtime (hrs)

Performance Efficiency Formula
Performance Efficiency (%) =
[Actual Production Rate (units per hour) / Best Production Rate (units per hour)] × 100

Quality Rate Formula
Quality rate % =
[(Total Units Produced – Defective Units Produced) / Total Units Produced] × 100

COMPONENT DEFINITIONS

Actual Production Rate
The rate at which an asset actually produces product during a designated time period.

Availability
The percentage of the time that the asset is actually operating (uptime) compared to when it is scheduled to operate. Also called operational availability.

Best Production Rate
The rate at which an asset is designed to produce product during a designated time period or the demonstrated best sustained rate, whichever is higher.

Defective Units Produced
The number of unacceptable units produced during a time period (e.g., losses, rework, scrap, etc.).

Downtime Event
An event when the asset is down and not capable of performing its intended function.

Idle Time
The time an asset is idle or waiting to run. The sum of the times when there is no demanded administrative idle time (e.g., not scheduled for production). Does not include equipment downtime (scheduled or unscheduled) and no feedstock or raw materials.

Performance Efficiency (Rate/Speed)
The degree to which the equipment operates at historical best speeds, rates and/or cycle times.

Quality Rate
The degree to which product characteristics meet the product or output specifications.

Scheduled Downtime
The time required to work on an asset that is on the finalized weekly maintenance schedule.

Scheduled Hours of Production
The amount of time an asset is scheduled to run (e.g., total available time, less idle time and less scheduled downtime).
Total Available Time
Annual Basis: 365 days/year x 24 hours/day = 8760 hours per year (Note: The addition of one more day per year must be made for leap year.) Daily Basis: 24 hours

Total Units Produced
The number of units produced during a designated time period.

Unscheduled Downtime
The time an asset is down for repairs or modifications that are not on the weekly maintenance schedule.

Uptime
The amount of time an asset is actively producing a product or providing a service. It is the actual running time

QUALIFICATIONS

1. Time Basis: See options below.

   Real Time – Hourly or per operating shift

   Daily – Summary report of OEE performance

   Period Trending – Daily, weekly, monthly, quarterly and/or annual comparisons
2. This metric is primarily used by maintenance, reliability, production and industrial engineers to capture asset performance data in order to identify improvement opportunities. It is also used by operations, maintenance and plant engineers as a relative indicator of asset performance from period to period in order to evaluate equipment stability and potential capacity for the purposes of production scheduling and capital investment justification.
3. Caution should be used when calculating OEE at a plant or corporate level. OEE percentage is a better measure of specific equipment effectiveness.
4. OEE is not a good measure for benchmarking assets, components or processes because it is a relative indicator of specific asset effectiveness over a period of time.

5. The OEE percentage should be used primarily as a relative internal improvement measure for a specific asset or single-stream process.
6. OEE is not a measure of maintenance effectiveness since most factors are not within the control of the maintainers.
7. If planned and scheduled maintenance is performed during idle time (e.g., when there is no demand for the asset), the time is not considered downtime. Note: This can result in misleading production availability values if demand increases, reducing or eliminating the opportunity to do planned and scheduled maintenance while the asset is idle.
8. The performance efficiency value cannot exceed 100%. To ensure this does not happen, the best production rate must be specified correctly. When determining best speed, rate or cycle time, plants must evaluate this based on historic information and whether or not the best speed is sustainable. Typically, time basis is the prior year. Sustainability varies by type of asset, but typically is greater than four hours with good quality production or four days with large process plants.
9. The quality rate should be first pass first time, meaning quality standards are met at the time of manufacturing without the need for rework.

SAMPLE CALCULATION

An example of the OEE percentage calculation based on OEE data for one day (24 hours) for Machine D operation is shown in Table 1 on the following page.

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Table 1. Example Calculation of OEE

Components	Data	Comments
Total available time	24 hours	24 hours in one day
Idle time	8 hours	Not required eight hours per day
Scheduled downtime		
No production, breaks, shift change, etc.	0.66 hours	Meeting & shift change
Planned maintenance	1.00 hours	Monthly PM
Total scheduled downtime	1.66 hours	
Unscheduled downtime		
Waiting for operator	0.46 hours	Operator distracted, on other tasks
Failure or breakdowns	0.33 hours	Mechanical drive coupling
Set-ups & changeover	0.26 hours	Two size changes
Tooling or part changes	0.23 hours	Screw station bits
Startup & adjustment	0.30 hours	First shift Monday
Input material flow	0.50 hours	Waiting for raw materials
Total unscheduled downtime	2.08 hours	
Total downtime (scheduled + unscheduled)	3.74 hours	1.66 + 2.08 = 3.74 hours
Uptime	12.26 hours	(24 – 8) – 3.74 = 12.26 hours
Availability	76.63%	12.26 / (24-8) x 100 = 76.63%
Performance efficiency losses	(Count)	
Minor stops	10 events	Machine jams
Reduced speed or cycle time	100 v.167 units	Design rate: 12.5 units/hour
Performance efficiency	59.88%	(100 / 167) x 100 = 59.88%
Quality & yield losses	(Count)	
Scrap product/output	2	Waste, non-salvageable
Defects, rework	1	
Yield/transition	5	Startup & adjustment related
Rejected units produced	8	2 + 1 + 5 = 8
Good units produced	92	100 – 8 = 92 good units
Quality rate	92%	(92 / 100) x 100 = 92%
Overall equipment effectiveness	42.21%	76.63 x 59.88 x 92.00 = 42.21%

Machine D averaged 42.21% in the current period. Assuming that Machine D OEE averaged 50.2% year-to-date and 45.06% in the prior period, an OEE trending downward warrants a review and analysis to understand the root causes and to identify and prioritize opportunities for improvement.

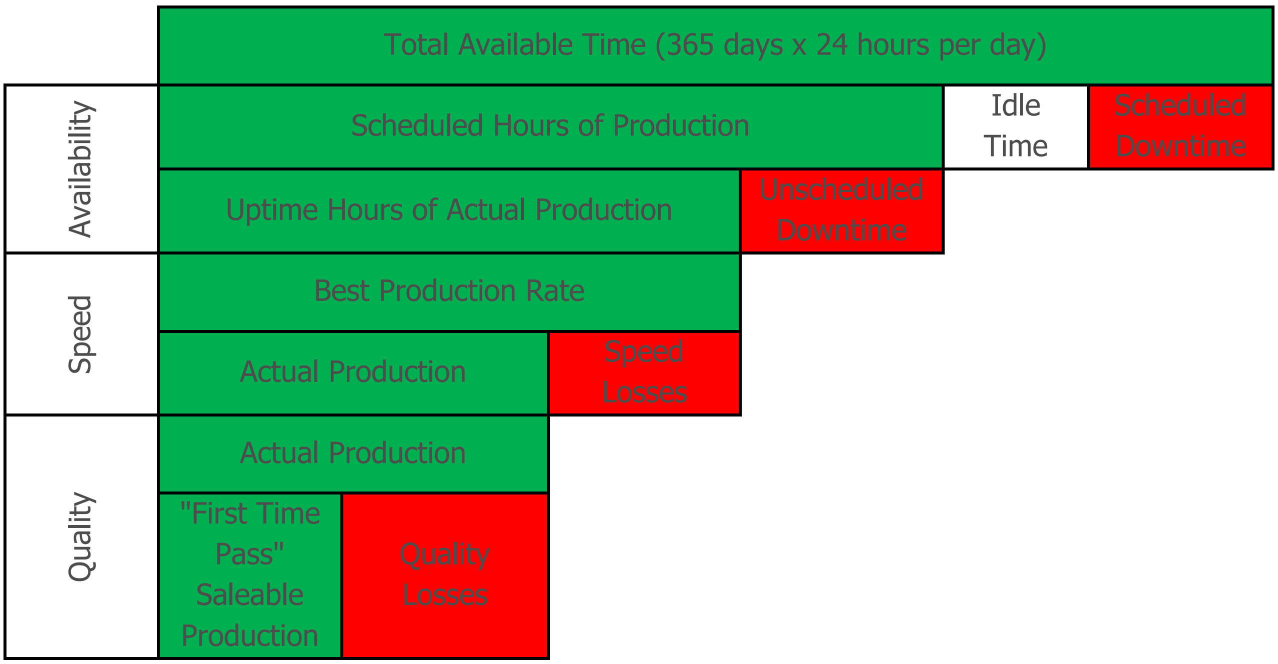

Figure 1. Overall Equipment Effectiveness Timeline

BEST- IN- CLASS TARGET VALUE

85% to 100% batch type manufacturing
90% to 100% continuous discrete manufacturing
95% to 100% continuous process
Availability >90%
Quality >99%
Performance >95% equals a 85% to 100% OEE

CAUTIONS

Caution should be used when calculating OEE at a plant or corporate level. OEE percentage is a better measure of specific equipment effectiveness. To calculate OEE at a plant level you must take each element to its basic form before combining availability, quality and performance since each element is a percentage. OEE is not a good measure for benchmarking assets, components or processes because it is a relative indicator of specific asset effectiveness over a period of time.

The OEE percentage should be used primarily as a relative, internal improvement measure for a specific asset or single-stream process. OEE is not a measure of maintenance effectiveness since most factors are not within the control of the maintainers.

If planned and scheduled maintenance is performed during idle time (e.g., when there is no demand for the asset), the time is not considered downtime. Note: This can result in misleading production availability values if demand increases, reducing or eliminating the opportunity to do planned and scheduled maintenance while the asset is idle. The performance efficiency value cannot exceed 100%. To ensure this does not happen, the best production rate must be specified correctly. OEE cannot exceed 100%.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

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MANUFACTURING PROCESS RELIABILITY METRIC

2.1.2 TOTAL EFFECTIVE EQUIPMENT PERFORMANCE (TEEP)

Published on June 7, 2010
Revised on August 3, 2016

DEFINITION

This metric is the measure of equipment or asset performance based on actual utilization time, availability, performance efficiency and quality of product or output over all the hours in the period. Total effective equipment performance (TEEP) is expressed as a percentage.

OBJECTIVES

This metric allows organizations to measure how well it extracts value from its assets. It provides the basis for setting improvement priorities and root cause analysis. Production losses are graphically depicted in Figure 1 based on the time elements in Figure 2.

FORMULAS

Total Effective Equipment Performance Formula
TEEP (%) = Utilization Time % × Availability % × Performance Efficiency % × Quality Rate %

Utilization Time Formula
Utilization Time % = [Total Available Time (hrs) – Idle Time (hrs)] / Total Available Time (hrs)

Availability Formula
Availability % = Uptime (hrs) / [Total Available Time (hrs) – Idle Time (hrs)] × 100

Uptime Formula
Uptime (hrs) = Total Available Time (hrs) – [Idle Time (hrs) + Downtime (hrs)]

Downtime Formula
Downtime (hrs) = Scheduled Downtime (hrs) + Unscheduled Downtime (hrs)

Performance Efficiency Formula
Performance Efficiency % =
[Actual Production Rate (units per hour) / Best Production Rate (units per hour)] × 100

Quality Rate Formula
Quality Rate % =
[(Total Units Produced – Defective Units Produced) / Total Units Produced] × 100

COMPONENT DEFINITIONS

Actual Production Rate
The rate at which an asset actually produces product during a designated time period.

Availability
The percentage of the time that the asset is actually operating (uptime) compared to when it is scheduled to operate. Also called operational availability.

Best Production Rate
The rate at which an asset is designed to produce product during a designated time period or the demonstrated best sustained rate, whichever is higher.

Defective Units Produced
The number of unacceptable units produced during a time period (e.g., losses, rework, scrap, etc.).

Downtime Event
An event when the asset is down and not capable of performing its intended function.

Idle Time
The time an asset is idle or waiting to run. The sum of the times when there is no demanded administrative idle time (e.g., not scheduled for production). Does not include equipment downtime (scheduled or unscheduled) and no feedstock or raw materials.

Performance Efficiency (Rate/Speed)
The degree to which the equipment operates at historical best speeds, rates and/or cycle times.

Quality Rate
The degree to which product characteristics meet the product or output specifications.

Scheduled Downtime
The time required to work on an asset that is on the finalized weekly maintenance schedule.

Scheduled Hours of Production
The amount of time an asset is scheduled to run (e.g., total available time, less idle time and less scheduled downtime).

Total Available Time
Annual Basis: 365 days/year x 24 hours/day = 8760 hours per year (Note: The addition of one more day per year must be made for leap year.) Daily Basis: 24 hours

Total Units Produced
The number of units produced during a designated time period.

Unscheduled Downtime
The time an asset is down for repairs or modifications that are not on the weekly maintenance schedule.

Uptime
The amount of time an asset is actively producing a product or providing a service. It is the actual running time.

Utilization Time
Time when the asset is scheduled to run divided by total available time, expressed as a percentage.

QUALIFICATIONS

1. Time basis: Monthly, quarterly and/or annually
2. This metric is used by corporate and plant product, operations and engineering groups to determine how well the organization is extracting value from its assets.
3. Caution should be used when calculating TEEP on a plant or corporate level. TEEP percentage is a better measure of specific equipment effectiveness.
4. Caution should be used when using TEEP for benchmarking different assets, equipment or processes because it is a relative indicator of specific asset effectiveness over a period of time.

5. TEEP is not primarily a measure of maintenance effectiveness since most of the factors are outside the control of the maintainers.
6. If TEEP is higher than OEE, there is an error in the calculation.
7. The performance efficiency value cannot exceed 100%. To ensure this does not happen, the best production rate must be specified correctly.
8. Best speed, rate or cycle time must be based on historic information and whether or not the best speed is sustainable. Sustainability varies by type of asset, but typically is greater than four hours with good quality production or four days with large process plants.
9. The quality rate should be first pass, first time. This means quality standards are met at the time of manufacturing without the need for rework.
10. It is assumed that the asset runs productively 24 hours a day, 365 days a year.
11. This metric can be used to identify idle time and potential capacity.

SAMPLE CALCULATIONS

TEEP data and calculation for one day (24 hours) of operation of a given asset are shown in Table 1 and Figure 1 on the next two pages.

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Table 1. Example Calculation of TEEP

Components	Data	Comments and Calculation
Total available time	24 hours	24 hours in one day
Idle time	8 hours	Not required 8 hours per day
Utilization time	66.67%	(24 – 8) / 24 x 100 = 66.67%
Scheduled downtime		
No production, breaks, shift change, etc.	0.66 hours	Meeting & shift change
Planned maintenance	1.00 hours	Monthly PM
Total scheduled downtime	1.66 hours	
Unscheduled downtime		
Waiting for operator	0.46 hours	
Failure or breakdowns	0.33 hours	Mechanical drive coupling
Set-ups & changeover	0.26 hours	Two size changes
Tooling or part changes	0.23 hours	Screw station bits
Startup & adjustment	0.30 hours	First shift Monday
Input material flow	0.50 hours	Waiting for raw materials
Total unscheduled downtime	2.08 hours	
Total downtime (scheduled + unscheduled)	3.74 hours	1.66 + 2.08 = 3.74 hours
Uptime	12.26 hours	(24 – 8) – 3.74 = 12.26 hours
Availability	76.63%	[12.26 / (24-8)] x 100 = 76.63%
Performance efficiency losses	(Count)	
Minor stops	10 events	Machine jams
Reduced speed or cycle time	100 v.167 units	Design rate: 12.5 units/hour
Performance efficiency	59.88%	(100 / 167) x 100 = 59.88%
Quality & yield losses	(Count)	
Scrap product/output	2	Waste, non-salvageable
Defects, rework	1	
Yield transition	5	Startup & adjustment related
Quality rate	92.00%	(92 / 100) x 100 = 92.00%
Total Effective Equipment Performance (TEEP)	28.14%	66.67 x 76.63 x 59.88 x 92.00 = 28.14%

In the example, since the asset is not required 24 hours per day, the TEEP is low. There is capacity available.

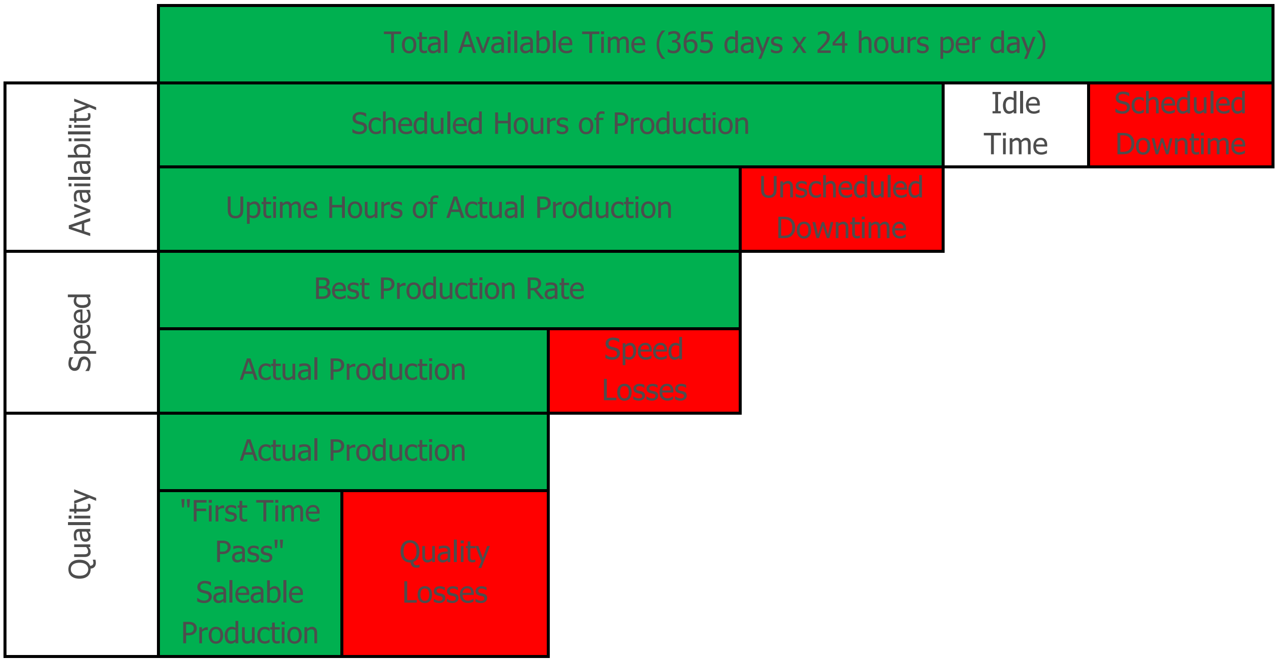

Figure 1. Total Effective Equipment Performance Timeline

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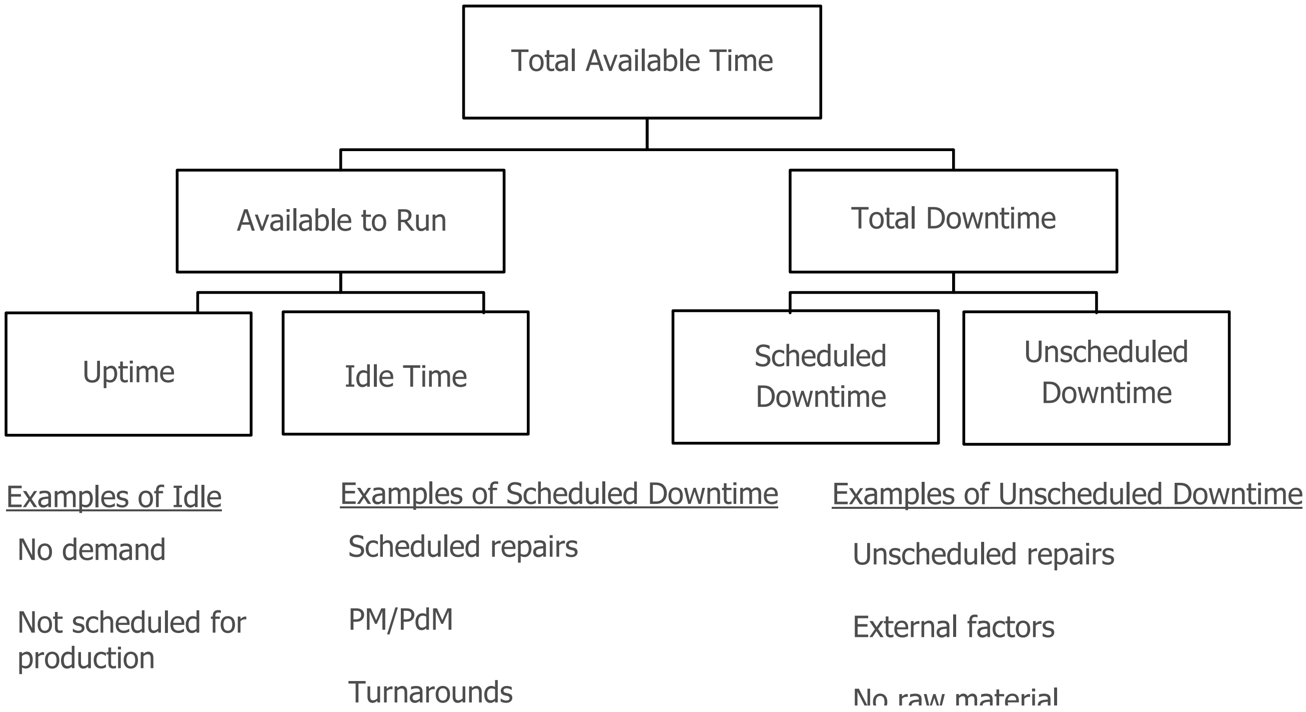

Figure 2. Time Element Chart

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee research indicates that best-in-class values for this metric are highly variable by industry vertical and type of facility. SMRP recommends organizations become involved in trade associations within their industry vertical, as these groups often publish such data about their industry. SMRP also encourages plants to use this metric to help manage your maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain useful information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Hansen, R. C. (2001), *Overall Equipment Effectiveness,* Industrial Press

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MANUFACTURING PROCESS RELIABILITY METRIC

2.2 AVAILABILITY

Published on October 12, 2010
Revised on August 3, 2016

DEFINITION

This metric is the percentage of time that the asset is actually operating (uptime) compared to when it is scheduled to operate. This is also called operational availability.

OBJECTIVES

Availability provides a measure of when the asset is either running or is capable of performing its intended function. It is a measure of an asset's ability to be operated if required.

FORMULA

Availability Formula
Availability % = {Uptime (hrs.) / [Total Available Time (hrs.) – Idle Time (hrs.)]} x 100

Uptime Formula
Uptime = Total Available Time – (Idle Time + Downtime)

Downtime Formula
Downtime = Scheduled Downtime + Unscheduled Downtime

COMPONENT DEFINITIONS

Idle Time
The time an asset is idle or waiting to run. The sum of the times when there is no demanded administrative idle time (e.g., not scheduled for production). Does not include equipment downtime (scheduled or unscheduled) and no feedstock or raw materials.

Operational Availability
The percentage of time that the asset is capable of performing its intended function (uptime plus idle time). Also called availability.

Scheduled Downtime
The time required to work on an asset that is on the finalized weekly maintenance schedule.

Total Available Time
Annual Basis: 365 days/year x 24 hours/day = 8760 hours per year (Note: The addition of one more day per year must be made for leap year.) Daily Basis: 24 hours

Unscheduled Downtime
The time an asset is down for repairs or modifications that are not on the weekly maintenance schedule.

Uptime
The amount of time an asset is actively producing a product or providing a service. It is the actual running time.

QUALIFICATIONS

1. Time Basis: Weekly, monthly, quarterly and annually.
2. This metric is used by corporate and plant managers to capture asset performance data as a basis for specific improvements related to design, operations and/or maintenance practices.
3. It should be used in conjunction with overall equipment efficiency (OEE) and total effective equipment performance (TEEP) in evaluating overall performance.
4. Do not confuse availability with reliability.
5. There are several variations of the definition of availability. SMRP's chosen definition is commonly used at the plant level. Academic definitions, such as achieved availability or inherent availability, correctly relate availability to mean time between failures (MTBF) or mean time to repair (MTTR). SMRP Guideline 6.0, Demystifying Availability, relates the SMRP definition to academic definitions and other variations.

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SAMPLE CALCULATION

An example of the availability calculation based on a performance period of one month (720 hours) for a single piece of equipment is shown in Table 1.

Table 1. Example Calculation of Availability

Components	Data	Comments
Total available time	720 hours	24 hours for 30 days
Idle time	240 hours	Power outage 20 hours, no demand 220 hours
Downtime Summary		
Scheduled downtime		
Preventative maintenance	30 hours	30 – 1 hour daily PMs
Scheduled shift breaks	19.8 hours	
Total scheduled downtime	49.8 hours	30 for PMs +19.8 shift breaks
Unscheduled downtime		
Waiting for operator	13.8 hours	
Failures or breakdowns	9.9 hours	
Setups and changeovers	16.8 hours	
Tooling or parts changes	6.9 hours	
Startups and adjustments	15.0 hours	
No feedstock	30.0 hours	
Total unscheduled downtime	92.4 hours	
Uptime	337.8	720 – 240 – 49.8 – 92.4
Availability: (% of time an asset is operating)	70.38%	337.8 / (720 – 240) x 100 = 70.38%

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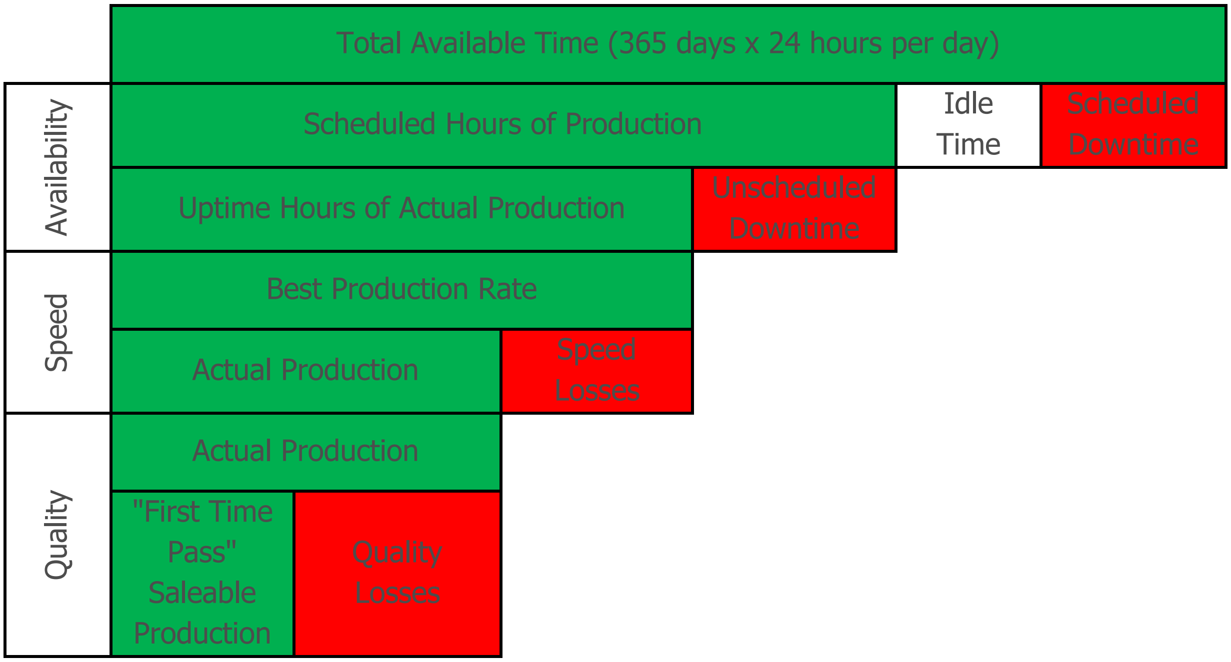

Figure 1. Overall Equipment Effectiveness Timeline

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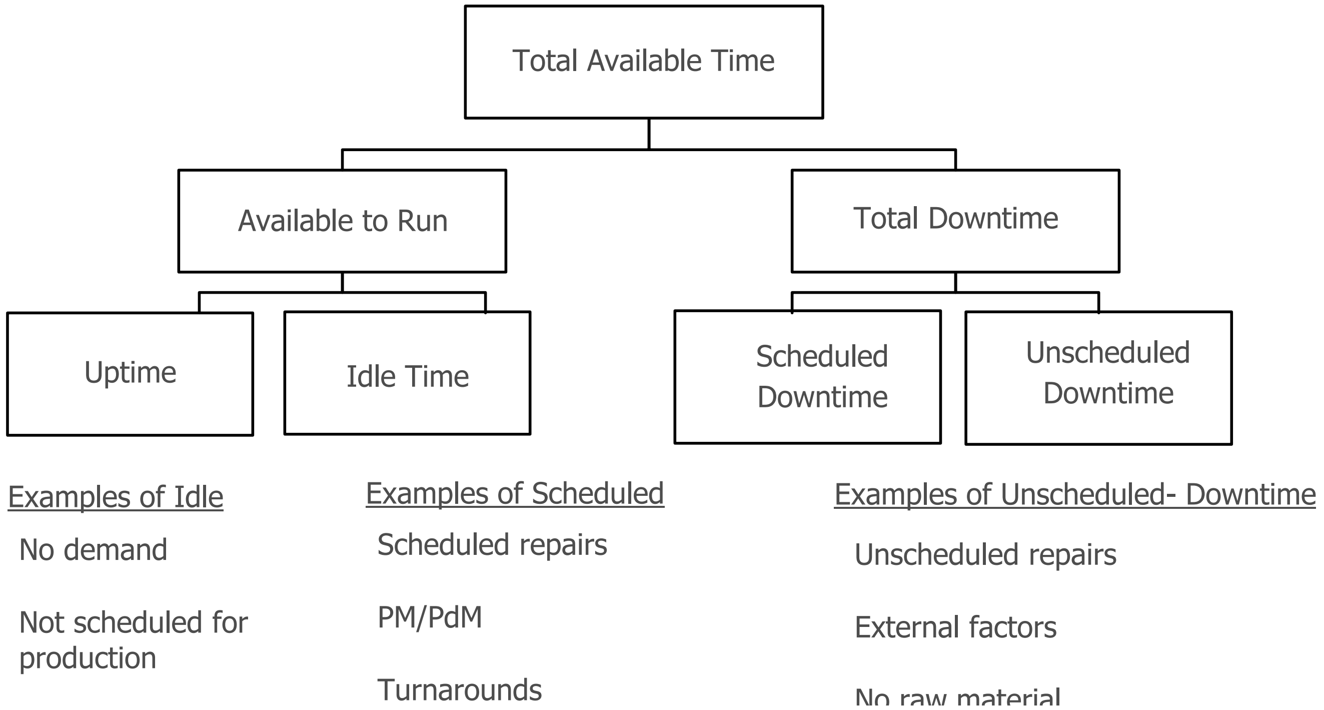

Figure 2. Time Element Chart

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee research indicates that best-in-class values for this metric are highly variable by industry vertical and facility type. SMRP recommends organizations become involved in trade associations within their industry vertical, as these groups often publish such data about their industry. SMRP also encourages plants to use this metric to help manage the maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain useful information to help make improvements to plant maintenance and reliability programs. This metric is aligned with 2.1.1 Overall Equipment Effectiveness (OEE) and 2.1.2 Total Effective Equipment Performance (TEEP).

CAUTIONS

Availability target should be set during the long-term or annual plan and based on business drivers. Drivers in determining the availability target can be raw product availability, market sales, spare capacity and higher than normal scheduled or unscheduled maintenance.

HARMONIZATION

This metric and its supporting definitions are harmonized with EN 15341 Indicators T1 and T2, as they all measure the same performance.

Note 1: Both the SMRP metric and the EN indicator use the term availability. The different use of the term availability reflects the cultural difference.

Note 2: EN 15341 looks at availability from an equipment perspective.

Note 3: The SMRP metric looks at availability from an operation perspective.

Note 4: EN 15341 indicators count only corrective and preventive maintenance as unavailability.

Note 5: The SMRP metric counts scheduled and unscheduled unavailability.

Note 6: The SMRP definition uptime is similar to the EN 13306 term operating time; consequently, the nominator in T1 is similar to the nominator in SMRP metric 2.2.

Note 7: The denominator in SMRP metric 2.2 is similar to the denominator in T2.

Conclusion: SMRP metric 2.2 is similar to the nominator in T1 and the denominator in T2.

Harmonization with indicator T1 in EN 15341 indicates that differences exist in component definitions.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating indicators T1 and T2. Additional information is available in the document *Global Maintenance and Reliability Indicators*, which is available for purchase in the SMRP Library.

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MANUFACTURING PROCESS RELIABILITY METRIC

2.3 UPTIME

Published on April 17, 2009
Revised on August 3, 2016

DEFINITION

This metric is the amount of time an asset is actively producing a product or providing a service. It is the actual running time. See Figure 2.

OBJECTIVES

This metric allows the evaluation of the total amount of time the asset has been capable of running to produce a product or to perform a service. It is used to compare the actual run time to planned potential capacity predictions.

FORMULA

Uptime = Total Available Time – (Idle Time + Total Downtime)

COMPONENT DEFINITIONS

Idle Time

The time an asset is idle or waiting to run. The sum of the times when there is no demanded administrative idle time (e.g., not scheduled for production). Does not include equipment downtime (scheduled or unscheduled) and no feedstock or raw materials.

Scheduled Downtime

The time required to work on an asset that is on the finalized weekly maintenance schedule.

Scheduled Hours of Production

The amount of time an asset is scheduled to run (e.g., total available time, less idle time and less scheduled downtime).

Total Available Time

Annual Basis: 365 days/year x 24 hours/day = 8760 hours per year (Note: The addition of one more day per year must be made for leap year.) Daily Basis: 24 hours

Total Downtime
The amount of time an asset is not capable of running. The sum of scheduled downtime and unscheduled downtime.

Unscheduled Downtime
The time an asset is down for repairs or modifications that are not on the weekly maintenance schedule.

Uptime
The amount of time an asset is actively producing a product or providing a service. It is the actual running time.

QUALIFICATIONS

1. Time Basis: Monthly and yearly (should coincide with financial reporting periods)
2. This metric is used by plant and/or corporate managers for improvement initiatives, capital investment justification, and asset rationalization. It is also used to identify latent capacity.

SAMPLE CALCULATION

A given asset is idle for 27 hours and down for 8 hours during a one-month period. Note: In the sample calculation a 30-day month (720 hours) is assumed

Uptime = Total Available Time – (Idle Time + Total Downtime)

Total Available Time = 30 days/month × 24 hours/day = 720 hours/30-day month

Idle Time = 27 hours

Total Downtime = 8 hours

Uptime = 720 – (27 + 8) = 685 hours

Uptime can also be expresses as a percentage (e.g., 685 hours / 720 hours = 95.1%)

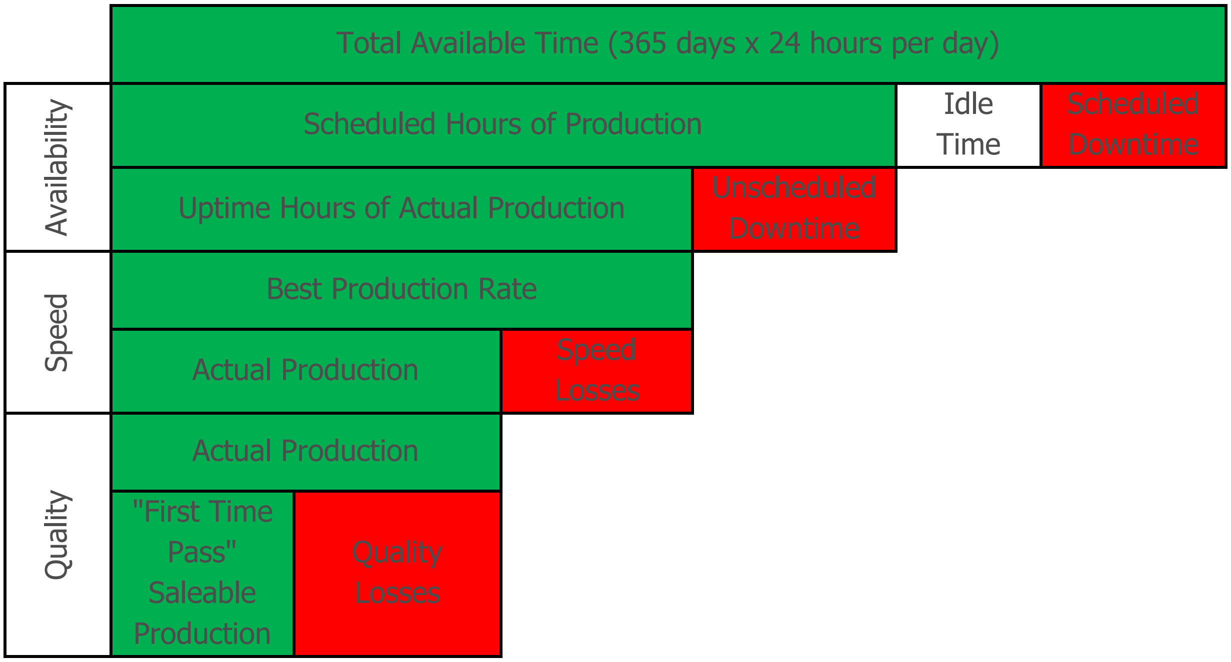

Figure 1. Overall Equipment Effectiveness Timeline

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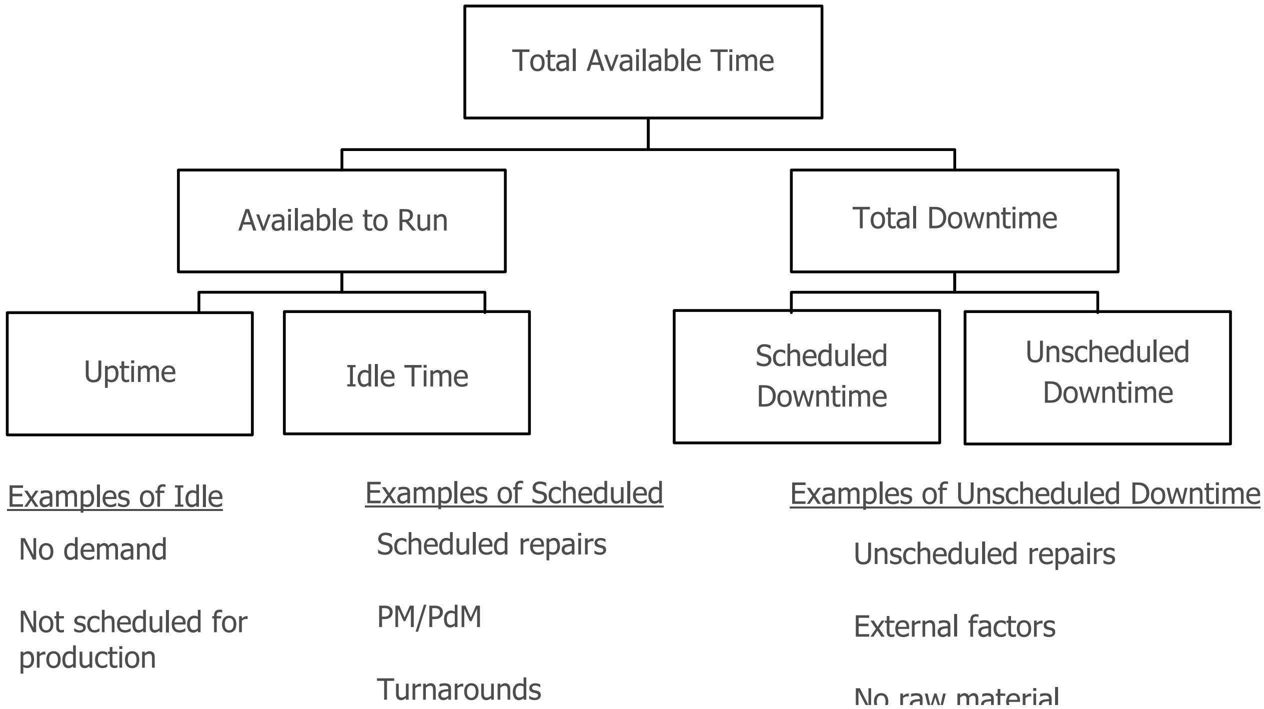

Figure 2. Time Element Chart

BEST-IN-CLASS TARGET VALUE

Greater than (>) 98% for continuous processing
Greater than (>) 95% for batch processing

CAUTIONS

The target value will vary by industry and process and does not take into account sites that maybe curtailed.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

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MANUFACTURING PROCESS RELIABILITY METRIC

2.4 IDLE TIME

Published on April 17, 2009
Revised on August 3, 2016

DEFINITION

This metric is the amount of time an asset is idle or waiting to run. It is the sum of the times when there is no demanded administrative idle time (e.g., not scheduled for production). Does not include equipment downtime (scheduled or unscheduled) and no feedstock or raw materials, as shown by Figure 2.

OBJECTIVES

This metric is used to evaluate the total amount of time, or percentage of time, the asset is idle or waiting to run. The metric is used to identify reasons for a loss in potential capacity.

FORMULA

Idle Time (IT) (hours) = No Demand (ND) + Administrative Idle Time (AIT)
IT = ND + AIT

Idle Time Percentage = Idle Time (IT) (hours) / Total Available Time (TAT) (hours)
IT (%) = IT (hours) / TAT (hours)

COMPONENT DEFINITIONS

Administrative Idle Time
The time that an asset is not scheduled to be in service due to a business decision (e.g., economic decision).

Idle Time
The time an asset is idle or waiting to run. The sum of the times when there is no demanded administrative idle time (e.g., not scheduled for production). Does not include equipment downtime (scheduled or unscheduled) and no feedstock or raw materials.

No Demand
The time that an asset is not scheduled to be in service due to the lack of demand for the product.

Total Available Time
Annual Basis: 365 days/year x 24 hours/day = 8760 hours per year (Note: The addition of one more day per year must be made for leap year.) Daily Basis: 24 hours

QUALIFICATIONS

1. Time basis: Monthly and yearly
2. This metric is used by plant, operations and corporate managers and production planners to identify latent capacity.
3. It can also be used for improvement initiatives, capital investment justification and asset rationalization.

SAMPLE CALCULATION

During a given month, an asset is down for 36 hours due to the failure of a downstream piece of equipment (no demand) and eight hours due to a shift change (administrative).

Idle Time (hours) = No Demand + Administrative Idle Time

Idle Time (hours) = 36 hours + 8 hours

Idle Time (hours) = 44 hours

Idle Time can also be expressed as a percentage.

A 30 day month = 30 days × 24 hours/day = 720 hours

Idle Time (percentage) = 44 hours / 720 hours

Idle Time (percentage) = 6.1%

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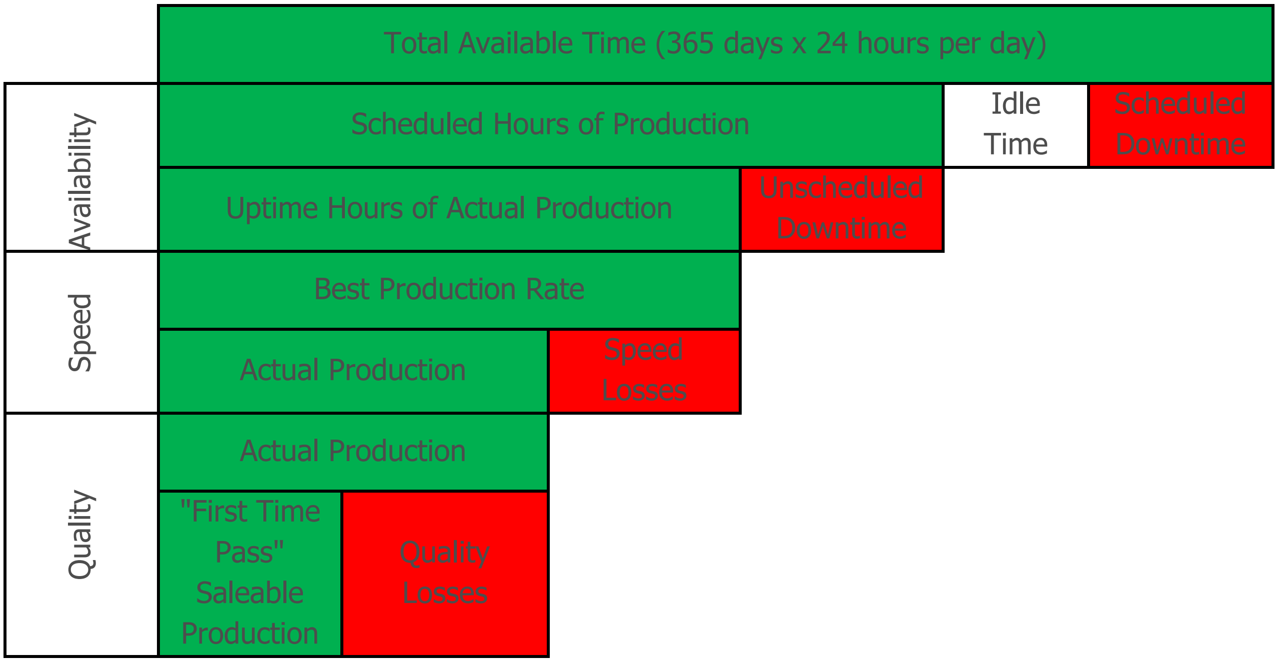

Figure 1. Overall Equipment Effectiveness Timeline

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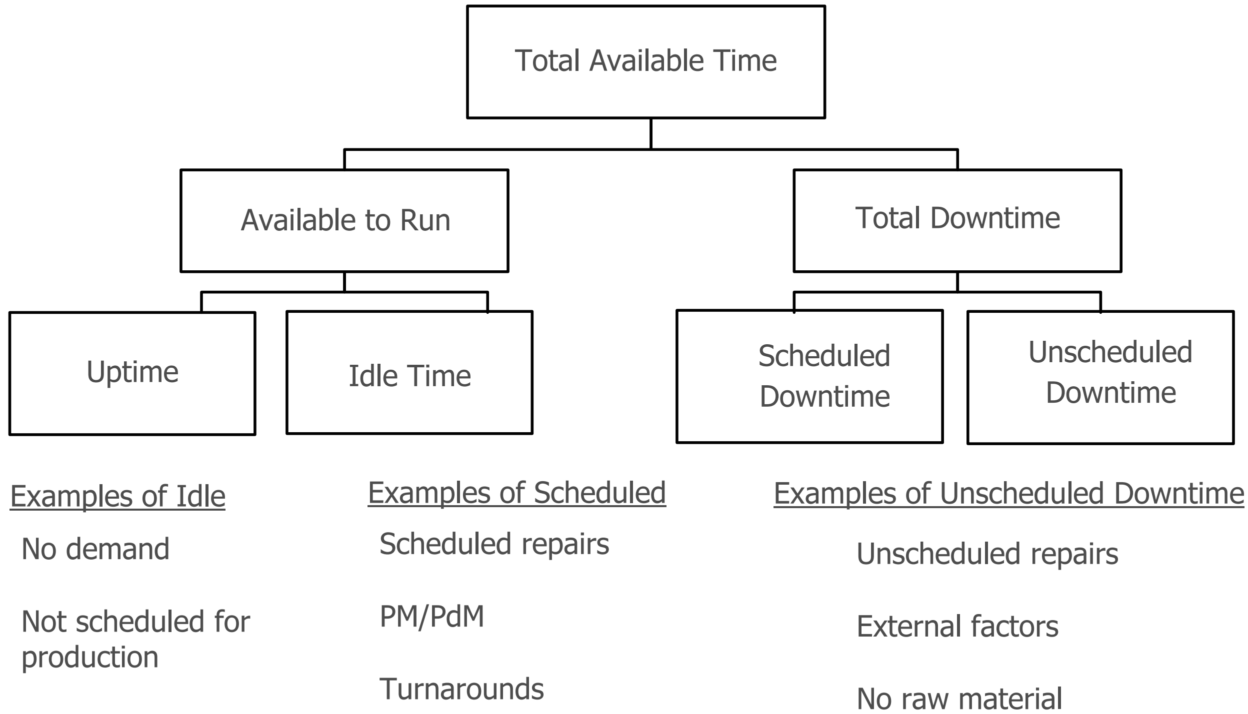

Figure 2. Time Element Chart

BEST-IN-CLASS TARGET VALUE

By definition, most idle time is beyond plant control; however, the value is still important to the business. Idle time represents capacity that has been paid for but is not being used – less is better.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

This metric is approved by consensus of SMRP Best Practice Committee.

MANUFACTURING PROCESS RELIABILITY METRIC

2.5 UTILIZATION TIME

Published on April 17, 2009
Revised on August 3, 2016

DEFINITION

This metric measures the percent of total time that an asset is scheduled to operate during a given time period, expressed as a percentage. The time period is generally taken to be the total available time (e.g., one year).

OBJECTIVES

The objective of this metric is to assess the amount of time an asset is intended to be service.

FORMULA

Utilization Time (percentage) =
[Total Available Time (hrs.) – Idle Time (hrs.)] / Total Available Time (hrs.)] × 100

COMPONENT DEFINITIONS

Idle Time
The time an asset is idle or waiting to run. The sum of the times when there is no demanded administrative idle time (e.g., not scheduled for production). Does not include equipment downtime (scheduled or unscheduled) and no feedstock or raw materials.

Operating Time
An interval of time during which the asset or component is performing its required function.

Total Available Time
Annual Basis: 365 days/year x 24 hours/day = 8760 hours per year (Note: The addition of one more day per year must be made for leap year.) Daily Basis: 24 hours

Utilization Time
Time when the asset is scheduled to run divided by total available time, expressed as a percentage.

QUALIFICATIONS

1. Time basis: Annually
2. This metric is used by corporate and plant product, operations and engineering groups to determine how well the organization is extracting value from its assets.
3. Utilization time is a component of SMRP Metric 2.1.2 Total Effective Equipment Performance (TEEP).

SAMPLE CALCULATION

A given asset is idle for 2,890 hours during a year.

Utilization Time (%) =
[Total Available Time (hrs.) – Idle Time (hrs.)] / Total Available Time (hrs.)] × 100

Utilization Time (%) = [[8670 (hrs.) - 2890 (hrs.)] / 8670 (hrs.)] × 100

Utilization Time (%) = 0.667 × 100

Utilization Time (%) = 66.7%

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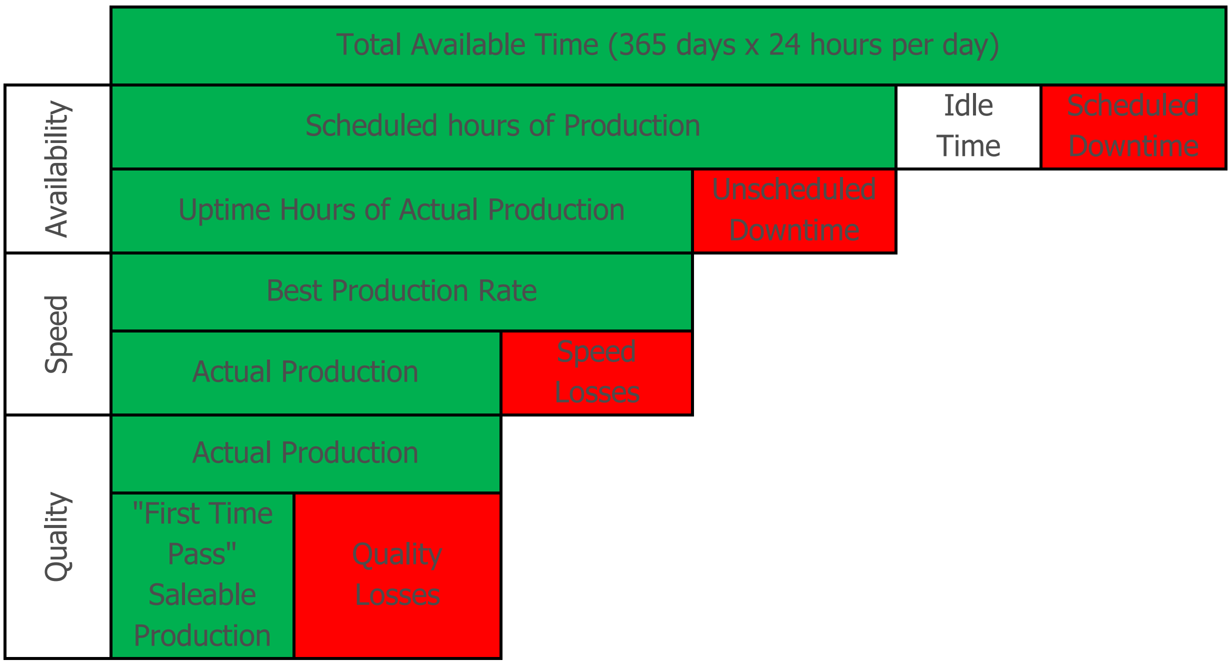

Figure 1. Overall Equipment Effectiveness Timeline

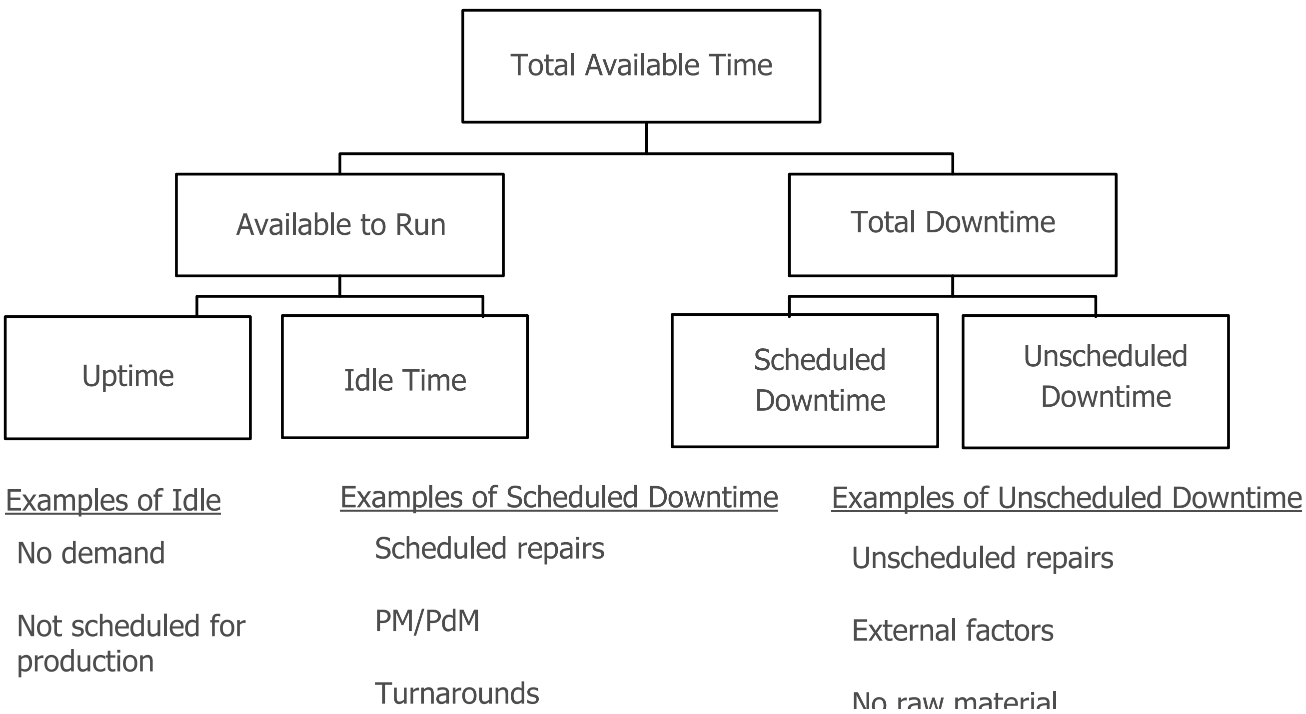

Figure 2. Time Element Chart

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee was unable to find any target ranges, minimum/maximum values, benchmarks or other references to target values for this metric. SMRP will update this metric as appropriate should future work help establish targets for this metric. While no target values are available, SMRP encourages plants to use this metric to help manage the maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain useful information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

Utilization time is impacted by many factors unrelated to elements of reliability, including market demand, availability of raw materials, availability of qualified labor resources, adequate price margins and other internal or external factors. Analysis of utilization time brings value in understanding true capacity.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

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Pillar 3
Equipment Reliability

MAINTENANCE & RELIABILITY BODY OF KNOWLEDGE

SMRP
Society for Maintenance & Reliability Professionals

EQUIPMENT RELIABILITY METRIC

3.1 SYSTEMS COVERED BY CRITICALITY ANALYSIS

Published on February 23, 2010
Revised on August 03, 2016

DEFINITION

This metric is the ratio of the number of systems in a facility for which a criticality analysis has been performed divided by the total number of systems in the facility, expressed as a percentage.

OBJECTIVES

This metric helps focus attention on those systems which pose the most serious consequences or adverse effects should they fail.

FORMULA

Systems Covered by Criticality Analysis (%) =
[Number of Critical Systems (for which a criticality analysis has been performed) / Total Number of Systems] × 100

The formula is depicted graphically in Figure 1.

COMPONENT DEFINITIONS

Critical Analysis
A quantitative analysis of events and faults and the ranking of these in order based on a weighted combination of the seriousness of their consequences and frequency of occurrence.

Critical Systems
The systems that are vital to continued operations, will significantly impact production or have inherent risks to personnel safety or the environment should they fail.

Systems
A set of interrelated or interacting elements. In the context of dependability, a system will have the following: (a) a defined purpose expressed in terms of required functions; (b) stated conditions of operation and (c) defined boundaries.

QUALIFICATIONS

1. Time Basis: Annually
2. This metric is used by corporate and plant risk managers and reliability engineers.
3. It should be calculated at the start of a maintenance improvement initiative and tracked in accordance with the initiative reporting schedule.
4. The assets included in each system should be defined by the management of that facility or organization. The term system must be related and transferred to the facility's technology (e.g., assets, functional locations, etc.).
5. The type of criticality analysis used can range from a simple criticality table to a formal failure modes and effects criticality analysis (FMECA).
6. Considerations for criticality analysis should include the environment, safety, production, quality and cost.
7. The analysis should be formally documented.
8. Criticality analysis should be performed on new systems prior to commissioning.
9. Before performing a criticality analysis, systems should be ranked and/or assessed to identify critical systems.
10. Critical systems should be separated from non-critical systems. See Figure 1.
11. The goal should be to have all critical systems covered by a criticality analysis.
12. Non-critical systems should be reviewed periodically to determine if anything has changed since the original assessment, installation and operation.

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SAMPLE CALCULATION

At a given plant, criticality analyses were performed on 337 of the facility's 1,811 systems.

Systems Covered by Criticality Analysis (%) =
[Number of Critical Systems (for which a criticality analysis has been performed) / Total Number of Systems] × 100

Systems Covered by Criticality Analysis (%) = (337 / 1811) × 100

Systems Covered by Criticality Analysis (%) = 0.186 × 100

Systems Covered by Criticality Analysis (%) = 18.6%

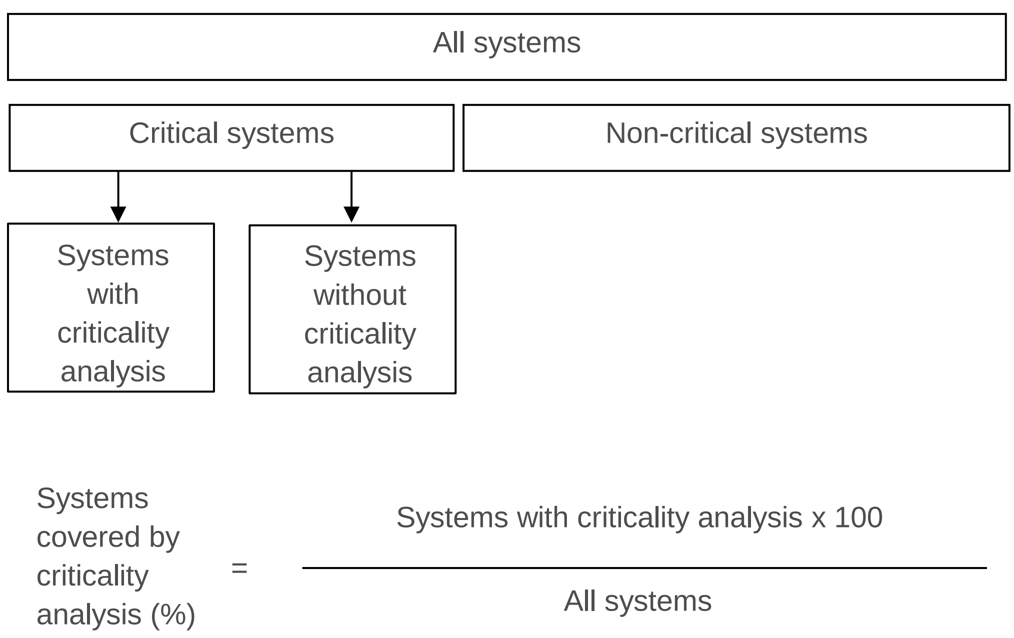

Figure 1. Calculation of the Metric: Systems Covered by Criticality Analysis

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee was unable to find any target ranges, minimum/maximum values, benchmarks or other references for target values for this metric. SMRP will update this metric as appropriate should future work help establish targets for this metric. While no target values are available, SMRP encourages plants to use this metric to help manage the maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain useful information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric and its supporting definitions are similar or identical to the indicator T18 in standard EN15341.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the T18 Indicator. Details are provided in the document *Global Maintenance and Reliability Indicators*, available in the SMRP Library.

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ISO/9000. (2005). Quality management systems – Fundamentals and vocabulary. Geneva, Switzerland: International Standards Organization.

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EQUIPMENT RELIABILITY METRIC

3.2 TOTAL DOWNTIME

Published on February 23, 2010
Revised on August 3, 2016

DEFINITION

This metric is the amount of time an asset is not capable of running. The sum of scheduled downtime and unscheduled downtime. See Figure 2.

OBJECTIVES

This metric allows the evaluation of the total amount of time the asset has not been capable of running. The metric can be used to identify problem areas and/or potential capacity in order to minimize downtime.

FORMULA

Total Downtime = Scheduled Downtime + Unscheduled Downtime

COMPONENT DEFINITIONS

Scheduled Downtime
The time required to work on an asset that is on the finalized weekly maintenance schedule.

Total Available Time
Annual Basis: 365 days/year x 24 hours/day = 8760 hours per year (Note: The addition of one more day per year must be made for leap year.) Daily Basis: 24 hours

Unscheduled Downtime
The time an asset is down for repairs or modifications that are not on the weekly maintenance schedule.

Weekly Schedule
The list of maintenance work to be done in the week. It is usually finalized three to four days before the start of the work week.

QUALIFICATIONS

1. Time Basis: Weekly, monthly and annually
2. This metric is used by plant and corporate managers for improvement initiatives, capital investment justification, asset rationalization and to identify latent capacity
3. To track rate-related losses, the metric overall equipment effectiveness (OEE) or utilization rate (UR) can be used.
4. Downtime will vary by industry. Caution must be used when comparing values across industries or industry sectors.
5. If downtime is required, the downtime should be scheduled such that outages can be planned.
6. Every effort should be made to avoid unscheduled downtime.

SAMPLE CALCULATION

For a given asset in a given month, the scheduled downtime is 50 hours and the unscheduled downtime is 25 hours. The total downtime would be:

Total Downtime = Scheduled Downtime + Unscheduled Downtime
Total Downtime = 50 + 25
Total Downtime = 75 hrs.

It can also be expressed as a percentage. For a 30 day month:

Total Downtime (%) = [75 hrs. / (30 days × 24 hrs./day)] × 100
Total Downtime (%) = [75 hrs. / 720 hrs.] × 100
Total Downtime (%) = 10.4 %

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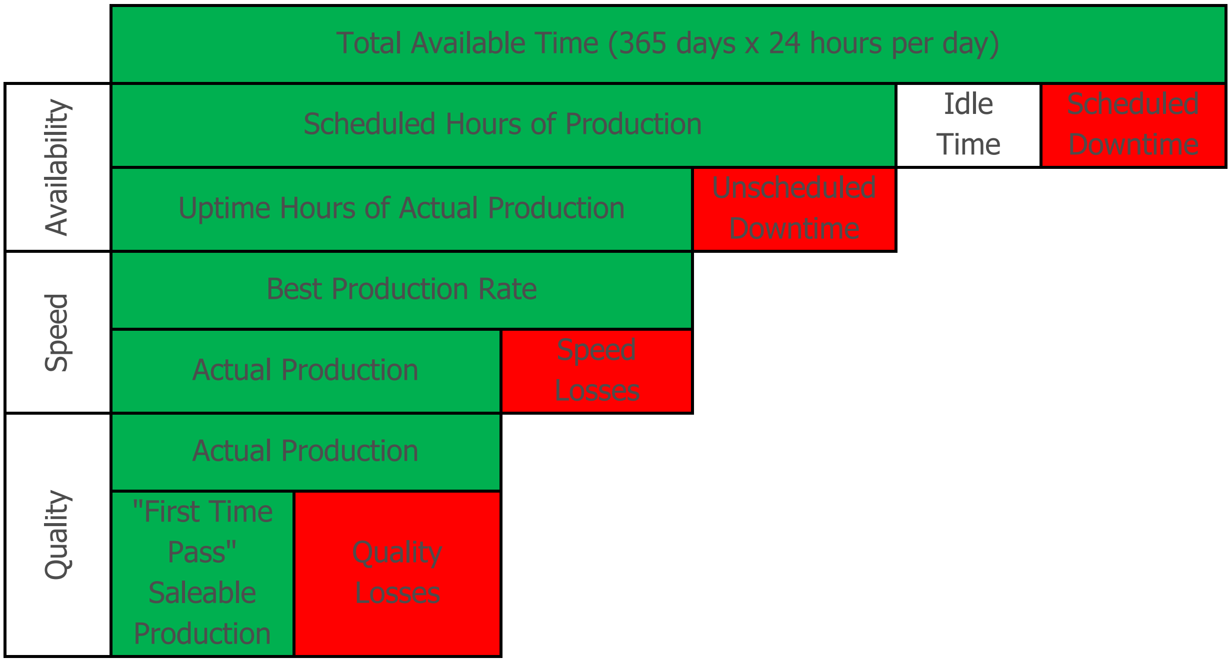

Figure 1. Overall Equipment Effectiveness Timeline

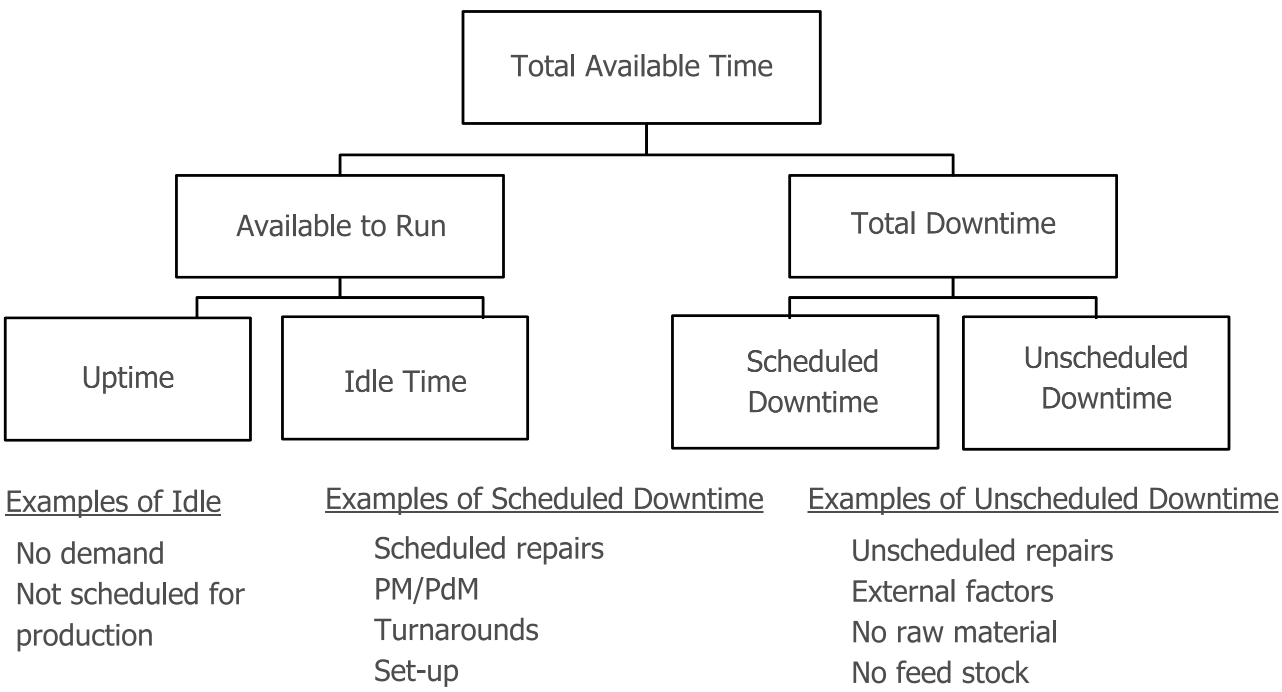

Figure 2. Time Element Chart

BEST-IN-CLASS VALUE

A value of <.5% to 2% total downtime caused by maintenance would represent a top quartile performance with variation dependent upon industry type and application of continuous versus batch processes.

CAUTIONS

Both the scheduled and unscheduled components of the total downtime formula are maintenance related activities only and are associated with maintaining asset capacity. Maintenance related downtime will vary by industry type.

Continuous processes will typically experience less maintenance related downtime than batch processes.

Additional factors, unrelated to maintenance, can increase total downtime and are not considered in the target value shown above.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Haarman, M. and Delahay, G. (2004). *Value driven maintenance; A new faith in maintenance*. The Netherlands: Mainnovation Publishing.

Hawkins, B. & Smith, R. (2004). *Lean maintenance–reduce costs improve quality, and increase market share*. Burlington, NY: Elsevier Butterworth Heinemann.

Mitchell, J. (2002). *Physical Asset Management Handbook* (3rd Ed). Houston, TX. Clarion Technical Publishers.

Moore, R. (2002). *Making common sense common practice – Models for manufacturing excellence* (2nd ed.). Burlington, NY: Elsevier Butterworth Heinemann.

EQUIPMENT RELIABILITY METRIC

3.3 SCHEDULED DOWNTIME

Published on April 16, 2009

DEFINITION

This metric is the amount of time an asset is not capable of running due to scheduled work, (e.g., work that is on the finalized weekly schedule). See Figure 1.

OBJECTIVES

This metric allows evaluation of the total amount of time the asset has not been capable of running due to scheduled work. The metric can be used to understand the impact of scheduled work on capacity and to minimize downtime.

FORMULA

Scheduled Downtime = Sum of Asset Downtime Identified on the Weekly Schedule

COMPONENT DEFINITIONS

Scheduled Downtime
The time required to work on an asset that is on the finalized weekly maintenance schedule.

Weekly Schedule
The list of maintenance work to be done in the week. It is usually finalized three to four days before the start of the work week.

QUALIFICATIONS

1. Time Basis: Weekly, monthly or yearly
2. This metric is used by plant managers and corporate managers for capital investment justification and asset rationalization. The metric can also be used to identify latent capacity.
3. Examples include: preventive maintenance, repair, turnarounds, etc. (See Figure 1)

4. A company or plant categorizes scheduled downtime at their discretion.
5. Actual hours (not estimated or scheduled hours) should be counted as scheduled downtime. For example, if the scheduled downtime for an asset was planned and scheduled for 20 hours, but the work actually took 30 hours, then 30 hours would be counted as scheduled downtime.
6. Where there is not a weekly schedule or categories of downtime on the weekly schedule, downtime that is known a week ahead would qualify as scheduled.
7. Downtime will vary by industry. Caution must be used when comparing values across industry sectors.
8. If downtime is required, the downtime should be scheduled such that outages can be planned.
9. Every effort should be made to avoid unscheduled downtime.

SAMPLE CALCULATION

For a given asset in a month, downtime identified on weekly schedules included 30 hours of preventive maintenance (PM) work, 10 hours of repair work and 10 hours of set-up time. These were the actual hours, not estimated hours. For this example, start-up and shutdown times have been considered negligible.

Scheduled Downtime = Sum of Asset Downtime Identified on the Weekly Schedule

Scheduled Downtime = PM Time + Repair Time + Set-up Time
Scheduled Downtime = 30 hours + 10 hours + 10 hours
Scheduled Downtime = 50 hours

Scheduled Downtime can also be expressed as a percentage. For a 30-day month:

Scheduled Downtime (%) = [50 hrs / (30 days × 24 hrs/day)] × 100
Scheduled Downtime (%) = [50 hrs / 720 hrs] × 100
Scheduled Downtime (%) = 6.9%

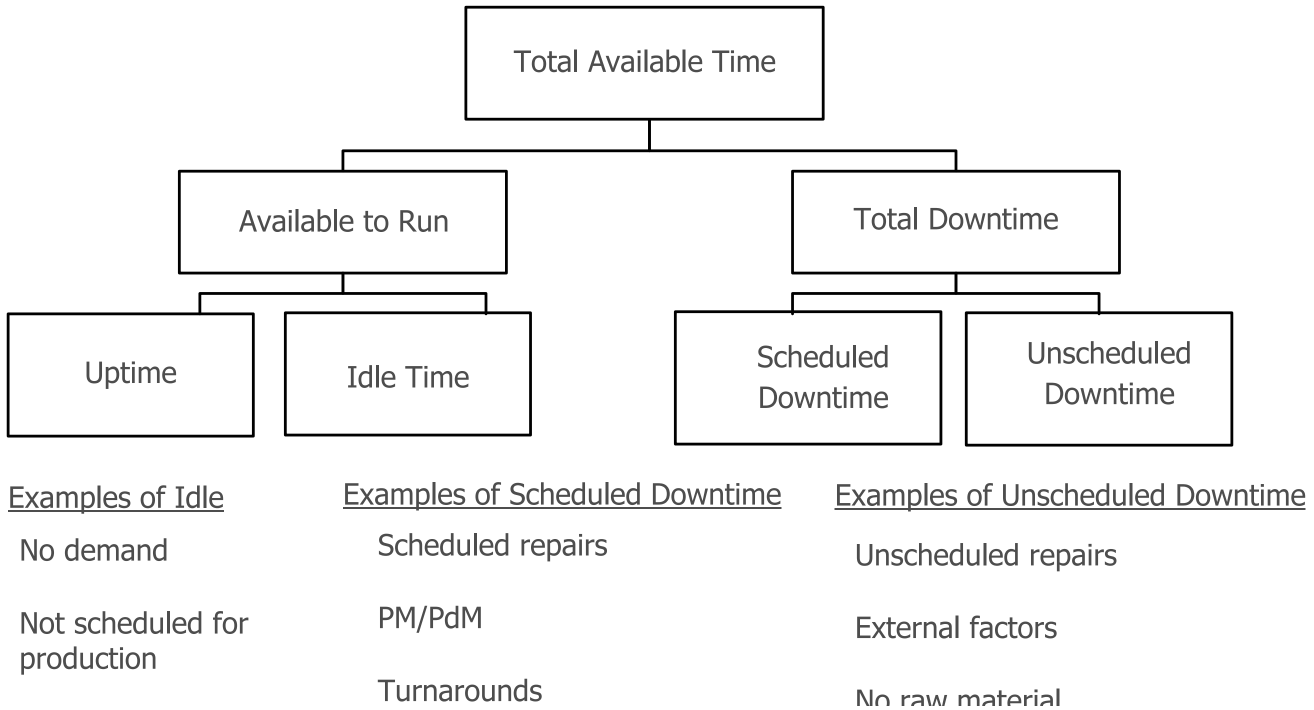

Figure 1. Time Element Chart

REFERENCES

None

EQUIPMENT RELIABILITY METRIC

3.4 UNSCHEDULED DOWNTIME

Published on April 16, 2009
Revised on August 3, 2016

DEFINITION

This metric is the amount of time an asset is not capable of running due to unscheduled repairs (e.g., repairs not on the finalized weekly maintenance schedule). See Figure 2.

OBJECTIVES

This metric allows evaluation of the total amount of time the asset has not been capable of running due to unscheduled repair work. The metric can be used to understand the impact of unscheduled work on capacity and maintenance productivity in order to minimize downtime.

FORMULA

Unscheduled Downtime = Sum of Asset Downtime Not Identified on the Weekly Schedule.

COMPONENT DEFINITIONS

No Feedstock or Raw Materials
The time that an asset is not scheduled to be in service due to a lack of feedstock or raw material.

Total Available Time
Annual Basis: 365 days/year x 24 hours/day = 8760 hours per year (Note: The addition of one more day per year must be made for leap year.) Daily Basis: 24 hours

Unscheduled Downtime
The time an asset is down for repairs or modifications that are not on the weekly maintenance schedule.

Weekly Schedule
The list of maintenance work to be done in the week. It is usually finalized three to four days before the start of the work week.

QUALIFICATIONS

1. Time Basis: Weekly, monthly and yearly
2. This metric is used by plant and corporate managers for improvement initiatives, capital investment justification and asset rationalization. The metric can also be used to identify latent capacity.
3. Figure 1 includes examples of unscheduled downtime causes. How an individual company categorizes unscheduled downtime is at their discretion.
4. Downtime will vary by industry. Caution must be used when comparing values across industry sectors.
5. If downtime is required, the downtime should be scheduled such that outages can be planned.
6. Every effort should be made to avoid unscheduled downtime.

SAMPLE CALCULATION

For a given asset in a month, the downtime that was not identified on the weekly schedule included 20 hours of repair work and 5 hours due to a lightning strike on the power line feeding the plant.

Unscheduled Downtime = Sum of Asset Downtime Not Identified on the Weekly Schedule
Unscheduled Downtime = Repair Time + Power Outage Time
Unscheduled Downtime = 20 hours + 5 hours = 25 hours

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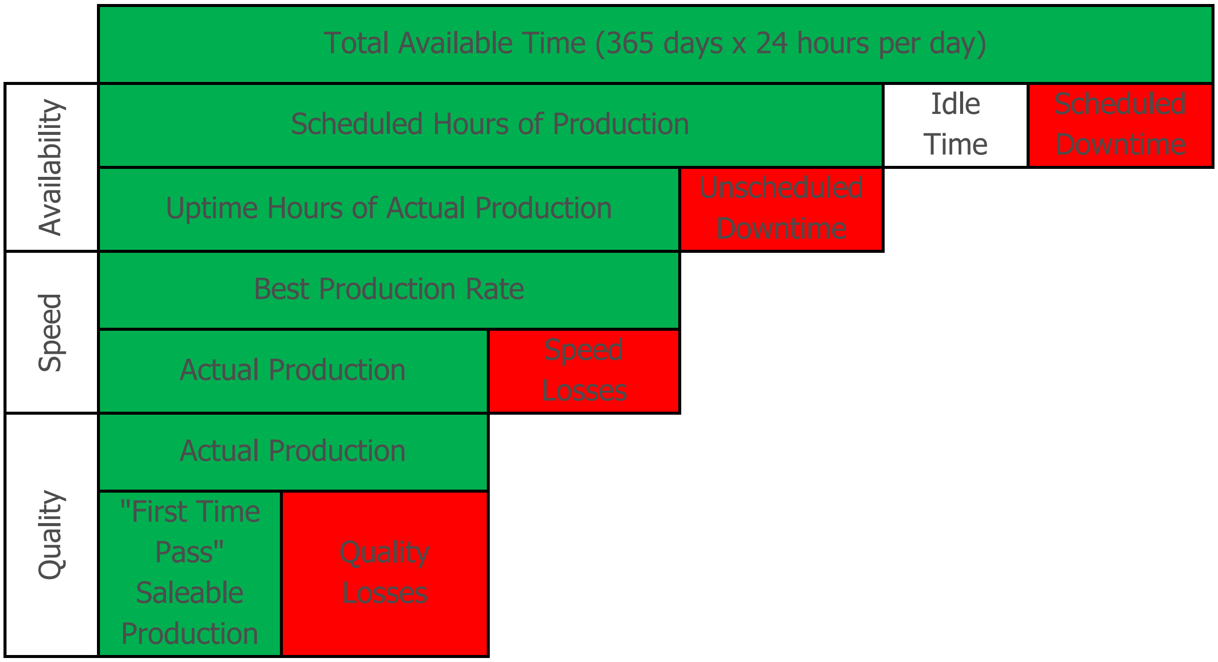

Figure 1. Overall Equipment Effectiveness Timeline

OEE can also be expressed as a percentage. For a 30 day month:

Unscheduled Downtime (%) = [25 hrs. / (30 days × 24 hrs./day)] ×100

Unscheduled Downtime (%) = (25 hrs. / 720 hrs.) × 100 = 3.5 %

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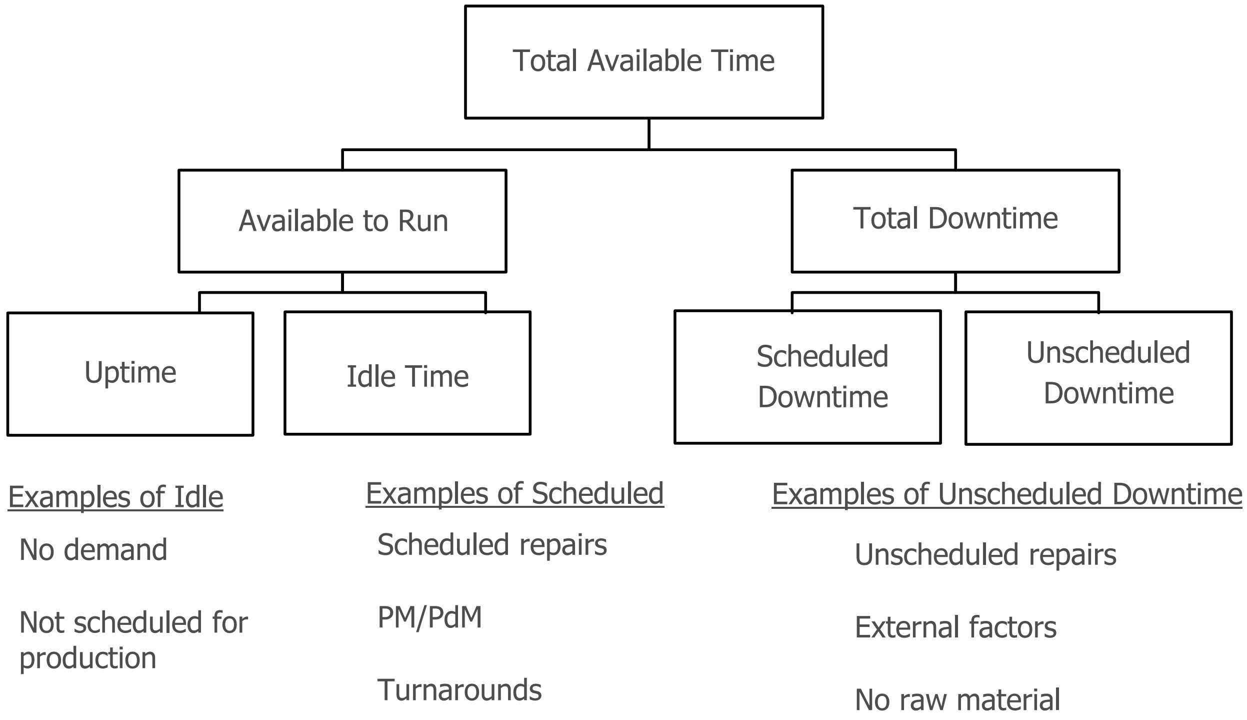


Figure 2. Time Element Chart

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee research indicates that best-in-class values for this metric are highly variable by industry vertical and type of facility. SMRP recommends that organizations become involved in trade associations within their industry vertical, as these groups often publish such data about their industry. SMRP also encourages plants to use this metric to help manage the maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain useful information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Approved by consensus of SMRP Best Practice Committee.

EQUIPMENT RELIABILITY METRIC

3.5.1 MEAN TIME BETWEEN FAILURES (MTBF)

Published on April 16, 2009

DEFINITION

This metric is the average length of operating time between failures for an asset or component. Mean time between failures (MTBF) is usually used primarily for repairable assets of similar type. Mean time to failures (MTTF), a related term, is used primarily for non-repairable assets and components (e.g., light bulbs and rocket engines). Both terms are used as a measure of asset reliability and are also known as mean life. MTBF is the reciprocal of the failure rate (λ), at constant failure rates.

OBJECTIVES

This metric is used to assess the reliability of a repairable asset or component. Reliability is usually expressed as the probability that an asset or component will perform its intended function without failure for a specified period of time under specified conditions. When trending, an increase in MTBF indicates improved asset reliability.

FORMULA

MTBF = Operating time (hours) / Number of Failures

COMPONENT DEFINITIONS

Failure
When an asset is unable to perform its required function.

Mean Life
A term used interchangeably with mean time between failures (MTBF) and mean time to failure (MTTF).

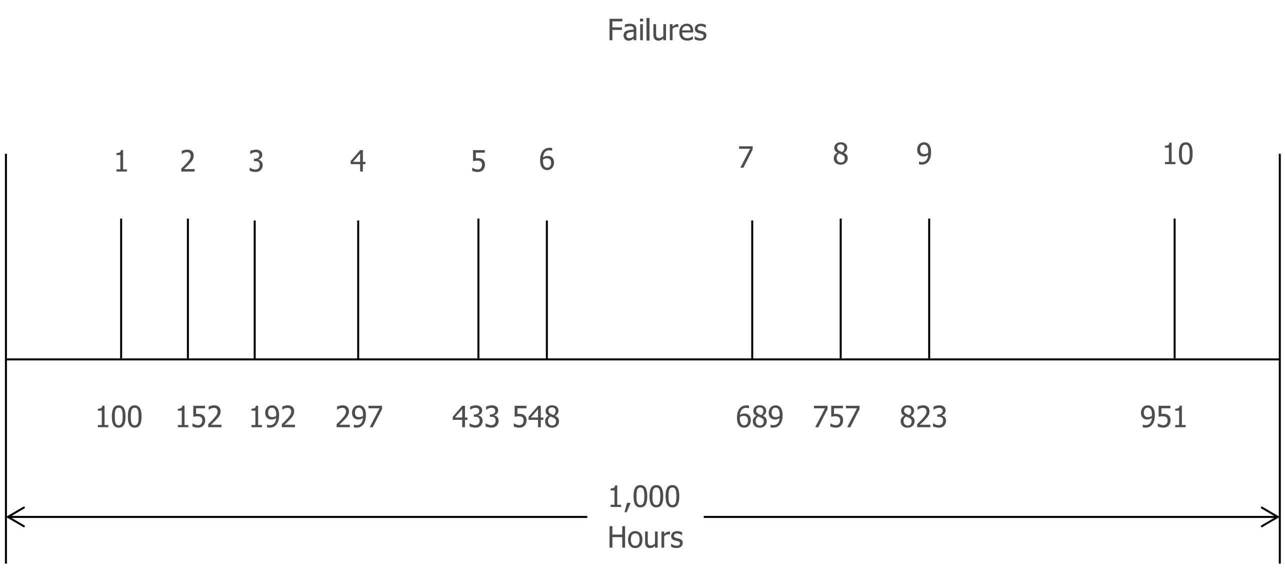
Operating Time
An interval of time during which the asset or component is performing its required function.

QUALIFICATIONS

1. Time Basis: Equipment dependent
2. This metrics is used by maintenance and reliability personnel.
3. It is best when used at asset or component level.
4. This metric should be trended over time for critical assets/components.
5. It can be used to compare reliability of similar asset/component types.
6. If MTBF for an asset or component is low, root cause failure analysis (RCFA) or failure modes and effects analysis (FMEA) should be performed to identify opportunities to improve reliability.
7. By using MTBF as a parameter for redesign, the repair time and maintenance cost of an asset could be reduced.

SAMPLE CALCULATION

Assume an asset had 10 failures in 1000 hours of operation, as indicated in the diagram below:



MTBF = Operating time (hours) / Number of Failures
MTBF = 1000 hours / 10 failures
MTBF = 100 hours

BEST-IN-CLASS VALUE

SMRP's Best Practices Committee research indicates that best-in-class values for this metric are variable depending on asset class and application. SMRP recommends that organizations use the MTBF metric as a means to monitor the impact of reliability improvement efforts on extending the time between failures. Combined with information from other metrics and by tracking and trending this metric, plants will gain useful information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric and its supporting definitions are similar or identical to EN 15341 indicator T17.

Note 1: SMRP uses the reciprocal value MTBF as failure rate. EN/IEC standards uses MTTF for the calculation of a failure rate (1/MTTF).

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the T17 indicator.

Additional information is available in the document *Global Maintenance and Reliability Indicators,* available for purchase in the SMRP Library.

REFERENCES

Gulati, R. (2009). *Maintenance and reliability best practices*. South Norwalk, CT: Industrial Press, Inc.

Mil-Std-721C. (1995). Washington, DC: United States Air Force.

EQUIPMENT RELIABILITY METRIC

3.5.2 MEAN TIME TO REPAIR OR REPLACE (MTTR)

Published on April 16, 2009

DEFINITION

This metric is the average time needed to restore an asset to its full operational capabilities after a failure. Mean time to repair or replace (MTTR) is a measure of asset maintainability, usually expressed as the probability that a machine can be restored to its specified operable condition within a specified interval of time regardless of whether an asset is repaired or replaced.

OBJECTIVES

The objective of this metric is to assess maintainability, including the effectiveness of plans and procedures.

FORMULA

MTTR = Total repair or replacement time (hours)/Number of repairs/replacement events

COMPONENT DEFINITIONS

Failure
When an asset is unable to perform its required function.

Repair/Replacement Event
The act of restoring the function of an asset after failure or imminent failure by repairing or replacing the asset.

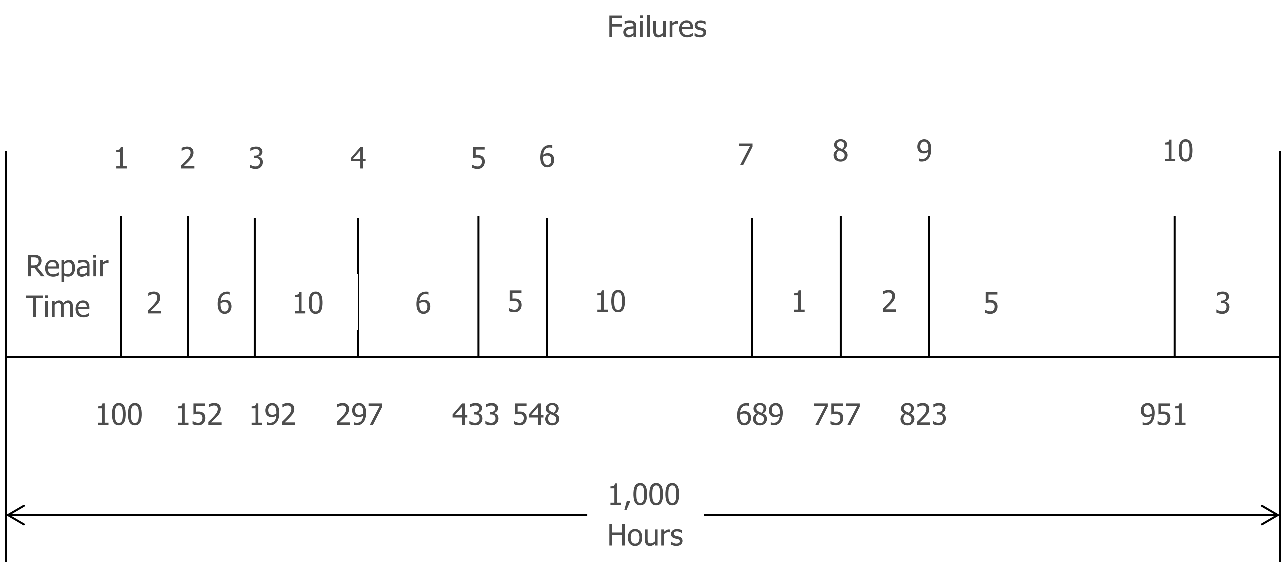
Repair/Replacement Time
The time required to restore the function of an asset after failure by repairing or replacing the asset. The duration of the repair or replacement begins when the asset ceases to operate to the time operability is restored. Includes time for checking the asset for its functionality prior to handing it over to operations.

QUALIFICATIONS

1. Indicator type: Lagging.
2. Time basis: Equipment dependent for a specified time period.
3. This metric is used by maintenance and reliability personnel.
4. MTTR provides the best data when used for the same type of asset/component in a similar operating context.
5. The craft worker's skill level, the existence and use of repair procedures and the availability of tools and materials could significantly reduce MTTR.
6. By using MTTR as a parameter for redesign, the repair time and maintenance cost of an asset could be reduced.

SAMPLE CALCULATION

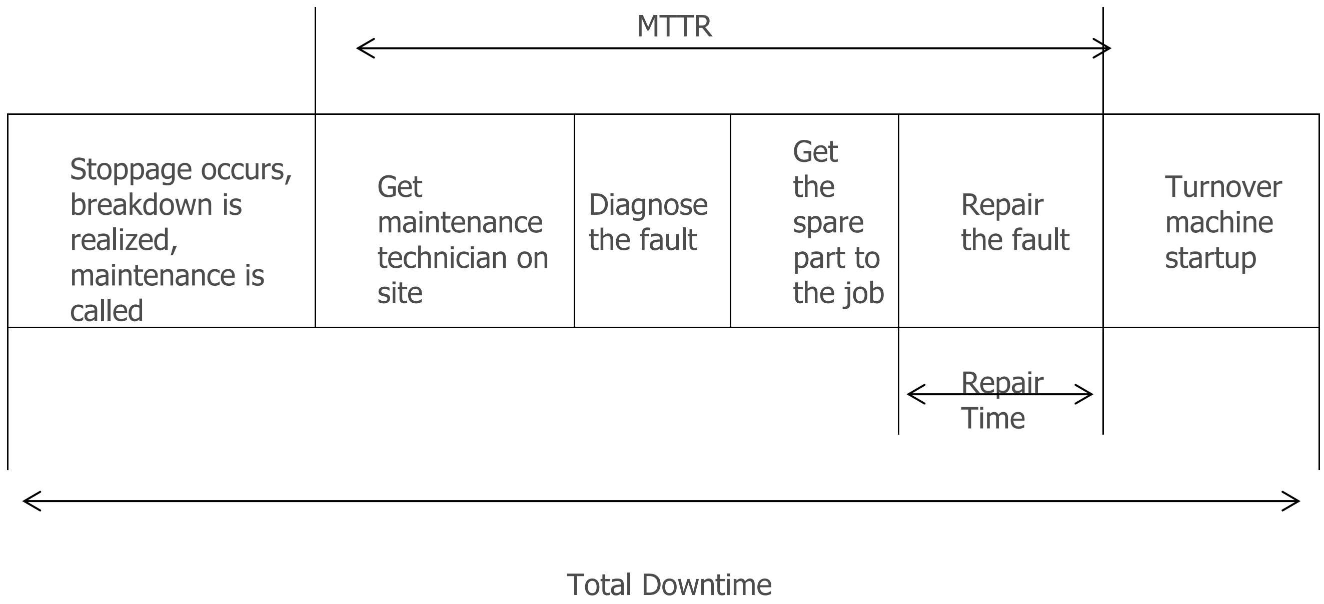
Assume an asset had 10 failures in 1000 hours of operation and repair times were 2, 6, 10, 6, 5, 10, 1, 2, 5 and 3 hours as shown in the diagram below.



MTTR = Total repair or replacement time (hours)/Number of repair/replace events
MTTR = (2+6+10+6+5+10+1+2+5+3)/10
MTTR = 50 hours/10
MTTR= 5 hours

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee research indicates that best-in-class values for this metric are variable depending on asset class and application. SMRP recommends that organizations use the MTTR metric as a means to monitor the impact of reliability improvement efforts on reducing the time to perform repairs. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs.



CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric and its supporting definitions are similar or identical to EN 15341 indicator T21.

Note 1: The difference between the SMRP metric and the EN15341 indicator T21 is in the glossary. EN 15341 refers to "R as restore" while SMRP refers to "R as repair". IEC 15191 term 191-13-08 approves "restoration," as well as "repair" Conclusion: The difference is academic.

Note 2: Both the SMRP metric and the EN metric include administrative and logistic delay in the calculation.

The SMRP definition for a failure is similar to the definition used in many ISO/IEC EN standards: "Termination of the ability to perform a required function."

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the T21 indicator.

Additional information is available in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

REFERENCES

Gulati, R. (2009). *Maintenance and reliability best practices*. South Norwalk, CT: Industrial Press, Inc.

Mil-Std-721C. (1995). Washington, DC: United States Air Force.

EQUIPMENT RELIABILITY METRIC

3.5.3 MEAN TIME BETWEEN MAINTENANCE (MTBM)

Published on June 22, 2009
Revised on August 11, 2015

DEFINITION

This metric is the average length of operating time between one maintenance action and another maintenance action for an asset or component. This metric is applied only for maintenance actions which require or result in function interruption.

OBJECTIVES

This metric is used to measure the effectiveness of the maintenance strategy for an asset or component. It can also be used to optimize the productivity of maintenance personnel by minimizing the number of trips to a specific asset or component.

FORMULA

Mean Time Between Maintenance (MTBM) =
Operating Time (hours)/Number of Maintenance Actions
MTBM = OT/NMA

COMPONENT DEFINITIONS

Maintenance Action
One or more tasks necessary to retain an item in, or restore it to, a specified operating condition. A maintenance action includes corrective, as well as preventive and predictive, maintenance tasks that interrupt the asset function.

Operating Time
An interval of time during which the asset or component is performing its required function.

QUALIFICATIONS

1. Time Basis: Equipment dependent
2. This metric is used by reliability engineers to measure the effectiveness of the reliability program of an asset or component.
3. It should be trended over time to see changes in performance. An increasing MTBM indicates improved maintenance effectiveness and reliability.
4. This metric can be used to compare maintenance effectiveness of similar asset and/or component types.
5. Assets or components with low MTBM warrant further analysis. For example, root cause failure analysis (RCFA) or failure modes and effects analysis (FMEA) may be used to determine how reliability can be improved.
6. By using MTBM as a parameter for redesign, repair time and costs can be reduced.

SAMPLE CALCULATION

A given asset had 10 corrective, 6 preventive and 3 predictive maintenance tasks (each resulting in operation interruption) over 1000 hours of operation.

Mean time between maintenance (MTBM) =
Operating time (hours) / number of maintenance actions
Mean time between maintenance (MTBM) = 1000 hour / (10 + 6 + 3)
Mean time between maintenance (MTBM) = 1000 hours / 19
Mean time between maintenance (MTBM) = 52.63 hours

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee research indicates that best-in-class values for this metric are variable depending on asset class and application. SMRP recommends that organizations use the MTBM metric as a means to monitor the impact of reliability improvement efforts on extending the time between maintenance activities. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Approved by consensus of SMRP Best Practice Committee.

EQUIPMENT RELIABILITY METRIC

3.5.4 MEAN DOWNTIME (MDT)

Published on June 27, 2009
Revised on August 3, 2016

DEFINITION

This metric is the average downtime required to restore an asset or component to its full operational capabilities. Mean downtime (MDT) includes the time from failure to restoration of an asset or component, including operations activities such as locking out and cleaning equipment.

OBJECTIVES

This metric is used to measure the effectiveness of the repair strategy for an asset or component. It can also be used to optimize the productivity of maintenance personnel by minimizing the time to repair a specific asset or component.

FORMULA

Mean Downtime (MDT) = Total Downtime (hours) / Number of Downtime Events
MDT = TDT / NDE

COMPONENT DEFINITIONS

Downtime Event
An event when the asset is down and not capable of performing its intended function.

Scheduled Downtime
The time required work on an asset that is on the finalized weekly maintenance schedule.

Total Downtime
The amount of time an asset is not capable of running. The sum of scheduled downtime and unscheduled downtime.

Unscheduled Downtime
The time an asset is down for repairs or modifications that are not on the weekly maintenance schedule.

QUALIFICATIONS

1. Time basis: Equipment dependent.
2. This metric is used by maintenance, industrial and reliability engineers to measure the effectiveness of the repair process for an asset or component.
3. It can be used to assess planning effectiveness and to identify productivity opportunities.
4. By using MDT as a parameter for redesign, the repair time and costs can be reduced.
5. The metric MDT can be broken into components for root cause analysis.
6. If the asset or component is not required 100% of the time, there may be more meaningful metrics to be used for improvement.

SAMPLE CALCULATION

A given asset had 10 downtime events in 1000 hours of operation. The scheduled downtimes due to these downtime events were 3, 9, 15, 8 and 6 hours respectively due to tooling change-outs, modifications, etc. The unscheduled downtimes due to these downtime events were 7, 14, 2, 4 and 8 hours respectively due to equipment failures.

Mean downtime (MDT) = Total downtime (hours) / Number of downtime events
Mean downtime (MDT) = [(3 + 9 + 15 + 8 + 6) + (7 + 14 + 2 + 4 + 8)] / 10
Mean downtime (MDT) = [41 + 35] / 10
Mean downtime (MDT) = 76 / 10
Mean downtime (MDT) = 7.6 hours

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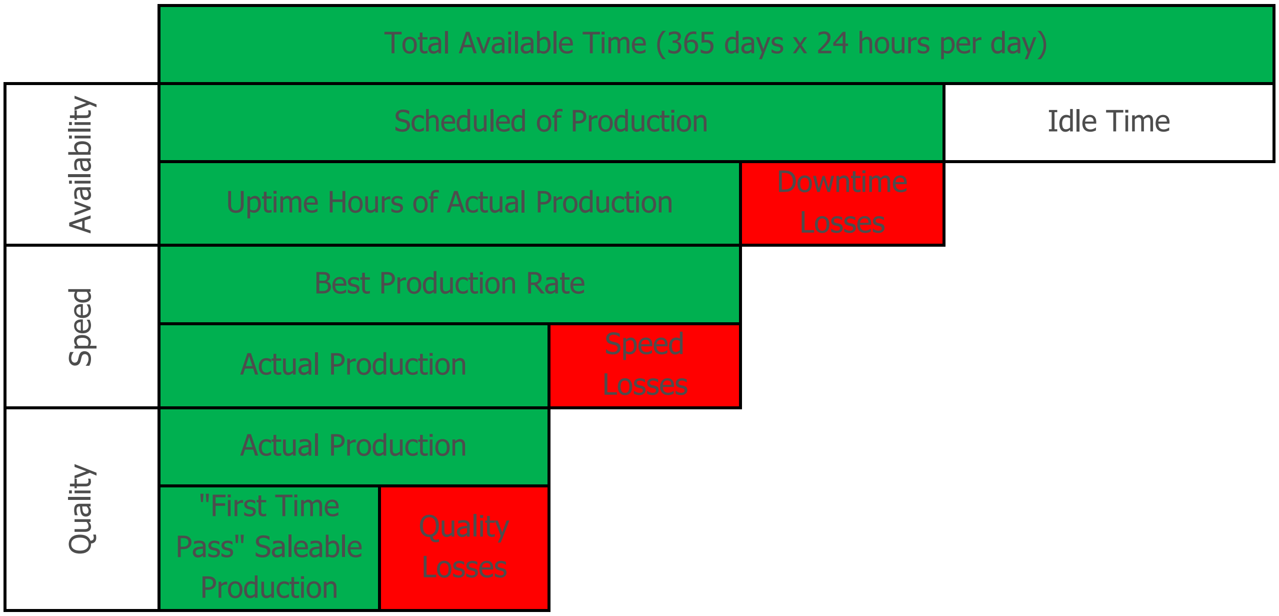

Figure 1. Overall Equipment Effectiveness Timeline

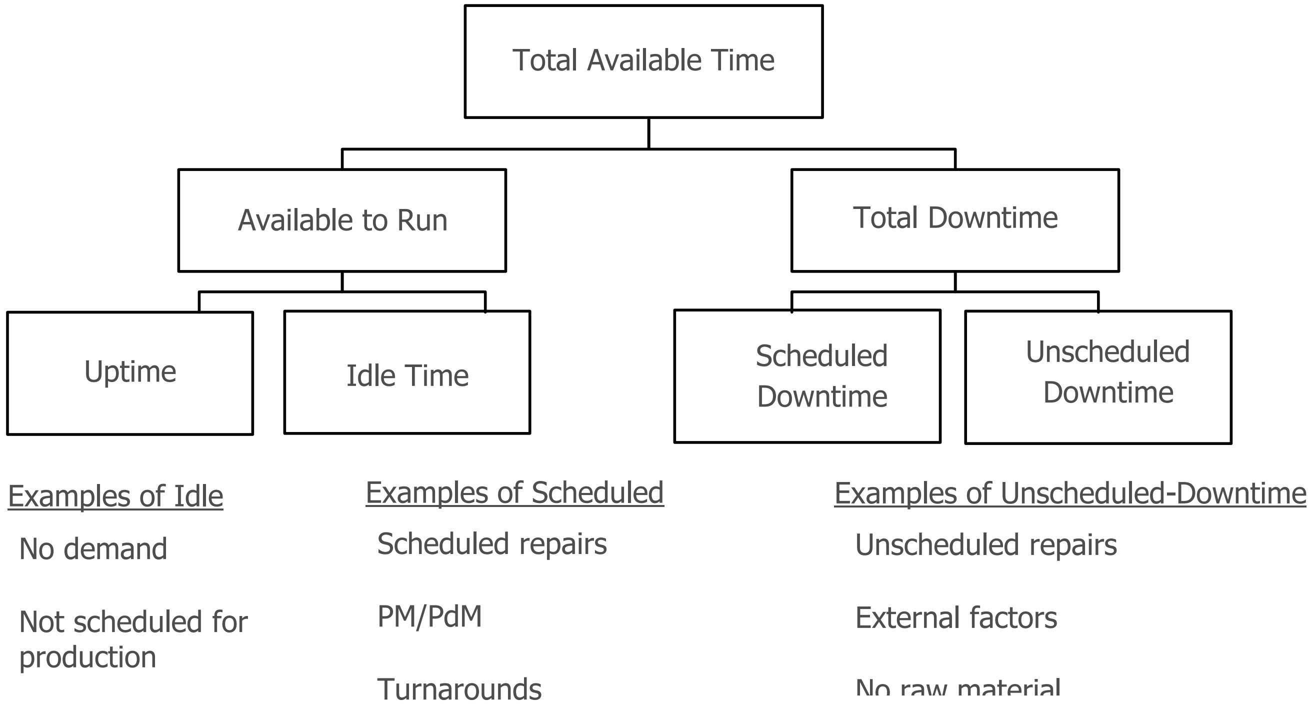

Figure 2. Time Element Chart

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee research indicates that best-in-class values for this metric are variable depending on asset class and application. SMRP recommends that organizations use the MDT metric as a means to monitor the impact of reliability improvement efforts on extending the time between maintenance activities. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Approved by consensus of SMRP Best Practice Committee.

EQUIPMENT RELIABILITY METRIC

3.5.5 MEAN TIME TO FAILURES (MTTF)

Published on April 16, 2009

DEFINITION

This metric is the average length of operating time to failure of a non-repairable asset or component (e.g., light bulbs, rocket engines). Another term, mean time between failures (MTBF), is primarily used for repairable assets and components of similar type. Both terms are a measure of asset reliability and are also known as mean life.

OBJECTIVES

This metric is used to assess the reliability of a non-repairable asset or component. Reliability is usually expressed as the probability that an asset or component will perform its intended function without failure for a specified time period under specified conditions. A higher MTTF indicates higher asset/component reliability.

FORMULA

MTTF = Operating Time to Failure (hours) / Number of Assets and/or Components Run to Failure

COMPONENT DEFINITIONS

Failure
When an asset is unable to perform its required function.

Operating Time
An interval of time during which the asset or component is performing its required function.

Space left blank intentionally

QUALIFICATIONS

1. Time Basis: Equipment dependent. Time measure above (hours) could also be substituted with other life measures (e.g., volume, number of batches, distance).
2. This metric is used by maintenance personnel and reliability engineers.
3. It is best when used at asset or component level.
4. MTTF can be used to compare reliability of similar asset/component types.
5. For low MTTF numbers, analysis should be performed, for example root cause failure analysis (RCFA) or failure modes and effects analysis (FMEA) to determine how reliability can be improved.

SAMPLE CALCULATION

If 10 non-repairable components had the following operating times to failure: 100, 152, 192, 297, 433, 485, 689, 757, 823, and 951, then MTTF would be calculated as shown below.

MTTF = Operating Time to Failure (hours) / Number of Components Run to Failure

MTTF = (100+152+192+297+433+485+689+757+823+951) / 10 = 4879/10 = 487.9 hours

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee research indicates that best-in-class values for this metric are variable depending on asset class and application. SMRP recommends that organizations use the MTTF metric as a means to monitor the impact of reliability improvement efforts on extending the time between failures for non-repairable assets. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Gulati, R. (2009). *Maintenance and reliability best practices*. South Norwalk, CT: Industrial Press, Inc.

Mil-Std-721C. (1995). Washington, DC: United States Air Force.

Pillar 4
Organization & Leadership

MAINTENANCE & RELIABILITY BODY OF KNOWLEDGE

Society for Maintenance & Reliability Professionals

ORGANIZATION & LEADERSHIP METRIC

4.1 REWORK

Published on April 16, 2009

DEFINITION

This metric is corrective work done on previously maintained equipment that has prematurely failed due to maintenance, operations or material problems. The typical causes of rework are maintenance, operational or material quality issues.

OBJECTIVES

This metric is used to identify and measure work that is the result of premature failures caused by errors in maintenance or operation (e.g., start-up) of the equipment or material quality issues. Measuring rework and its root causes enables plant management to develop and implement effective strategies designed to minimize or eliminate these errors. Typical strategies include: maintenance training, operations training, defective parts elimination, maintenance work procedures development or revision, operating procedures development or revision and improved purchasing and/or warehouse practices.

FORMULA

Rework (%) =
[Corrective Work Identified as Rework (hours) / Total Maintenance Labor Hours] × 100

COMPONENT DEFINITIONS

Corrective Work
Work done to restore the function of an asset after failure or when failure is imminent.

Total Maintenance Labor Hours
Expressed in hours and includes all maintenance labor hours for normal operating times as well as outages, shutdowns and turnarounds. If operator hours spent on maintenance activities are captured, they should be included in the numerator and denominator of all applicable metrics. Include labor hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not

include labor hours used for capital expansions or improvements. Typically, total maintenance labor hours do not include temporary contractor labor hours.

QUALIFICATIONS

1. Time Basis: Monthly
2. This metric is used by maintenance and operations personnel to measure the amount of maintenance labor that is caused by maintenance or operation errors and/or material quality issues.
3. This metric focuses on the asset, not on individual jobs or activities.
4. The percentage of rework should be very low.
5. To capture rework, there must be a way to identify and capture corrective maintenance labor caused by maintenance or operation errors and/or material quality issues. A separate work request or work order should be used to capture rework. Using an existing work request or work order can mask rework.
6. Rework should be captured by function, craft, crew and/or vendor for effective root cause analysis.

SAMPLE CALCULATION

A total of 1000 maintenance labor hours are worked in a month. A total of 40 hours are for corrective work identified as rework.

Rework (%) = [Corrective Work Identified as Rework (hours) / Total Maintenance Labor Hours] × 100

Rework (%) = (40 hours / 1000 hours) × 100

Rework (%) = 4%

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee was unable to find any target ranges, minimum/maximum values, benchmarks or other references for target values for this metric. SMRP will update this metric as appropriate should future work help establish targets for this metric. While no target values are currently available, SMRP encourages plants to use this metric to help manage the maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Approved by consensus of SMRP Best Practice Committee.

ORGANIZATION & LEADERSHIP METRIC

4.2.1 MAINTENANCE TRAINING COST

Published on April 16, 2009

DEFINITION

This metric is the cost for formal training that internal maintenance employees receive annually. It is expressed as cost per employee.

OBJECTIVES

The objective of this metric is to measure the formal training of internal maintenance employees. This metric is also used to trend the investment in the skills of internal maintenance employees.

FORMULA

Maintenance Training Cost (per employee) =
Total Maintenance Training Cost / Number of Internal Maintenance Employees

This metric can also be expressed as a percentage of the total maintenance labor cost.
Maintenance Training Cost (%) =
(Total Maintenance Training Cost / Total Internal Maintenance Employee Labor Costs) × 100

This metric can also be calculated by maintenance craft or job classification (e.g., mechanic, planner, etc.).

Maintenance Training Cost (by craft or job classification) =
Total Maintenance Training Cost (by craft or job classification) / Number of Maintenance Employees (by craft or job classification)

COMPONENT DEFINITIONS

Internal Maintenance Employees
All personnel, salaried and hourly, direct and indirect, who are responsible for executing work assignments pertaining to the maintenance of physical assets and components. Same as maintenance employee.

Maintenance Employees
All personnel, salaried and hourly, direct and indirect, who are responsible for executing work assignments pertaining to the maintenance of physical assets and components. Same as internal maintenance employees.

Total Internal Maintenance Employee Labor Cost
Includes all internal maintenance labor costs (including benefits), both straight time and overtime, for all direct and indirect maintenance employees. Includes maintenance labor costs for normal operating times, as well as outages/shutdowns/turnarounds. Also includes labor for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Includes the cost for maintenance work performed by operators. Does not include labor used for capital expenditures for plant expansions or improvements or contractor labor cost. Does not include janitorial cost or other similar costs not associated with the maintenance of plant equipment.

Total Maintenance Training Cost
The sum of all costs for formal training that is directed at improving job skills for maintenance employees. Training cost should include all employee labor, travel expenses, materials, registration fees, instructor fees, etc.

Training
Instruction provided in a formal setting, and it will typically include classroom and hands-on training with testing to confirm comprehension. Examples of training are safety (LOTO, JSA, etc.), interpersonal skills development (leadership, ESL, supervisory, etc.), math skills, computer skills, use of CMMS, job planning, reliability (FMEA, RCFA, etc.), problem solving, blueprint reading, alignment, balancing, lubrication, welding, all certifications (CMRP, CMRT, vibration, thermography, ultrasound, etc.), pneumatics, hydraulics, fasteners, use of specialized tools, equipment specific training, etc. Attendance at conventions and seminars is also credited as training, as long as the subjects fall within the SMRP Body of Knowledge.

QUALIFICATIONS

1. Time basis: Annually
2. This metric is used by maintenance managers and supervisors to measure the investment in internal maintenance employee skills.
3. Training should be formal documented training.
4. Testing should be included to measure employee comprehension.

5. Individual training needs assessments are useful to identify specific skills and knowledge gaps.
6. Internal maintenance employee skills assessments can be used to identify and quantify overall skills and knowledge gaps that can be used to develop a comprehensive maintenance training program.
7. It is recommended that skills and knowledge gaps be captured by craft or job classification (mechanic, electrician, planner, supervisor, etc.). If broken out, the measurement would be 'average training costs/job designation/year.'
8. Calculations can be made in any currency (e.g., Euros). Currency conversions should be treated with caution as conversion rates fluctuate continuously.
9. To compare across countries or currencies, it is recommended that SMRP Best Practice Metric Maintenance Training Hours 4.2.2 be used to normalize the results and enable valid comparisons.

SAMPLE CALCULATION

A given maintenance organization consists of 22 internal maintenance employees. Specifically, a maintenance manager, maintenance engineer, planner, two foremen, two supervisors, 10 mechanics, four electricians and a storeroom clerk. Total internal maintenance employee labor costs for the year was $1,162,000. Records are kept for all formal training received throughout the year. Training costs during the year included:

Maintenance Training Cost

$ 0	Safety (completed in-house)
$ 6,500	Laser alignment
$ 7,000	Hydraulic systems
$ 6,500	Circuit analysis
$ 6,000	Job planning
$ 1,600	Team building
$ 0	Math skill (completed in house)
$ 3,000	Annual SMRP Conference (registration costs, travel, etc.)
$ 4,800	Storeroom management
$35,400	**Annual Maintenance Training Cost**

Employee Labor Training Cost

$ 7,260	Safety
$ 7,079	Laser alignment
$ 7,079	Hydraulic systems
$ 1,965	Circuit analysis
$ 3,660	Job planning
$ 4,850	Team building
$ 1,200	Math skill
$ 3,335	Annual SMRP Conference (time)
$ 3,000	Annual SMRP Conference (registration costs, travel, etc.)
$ 2,530	Storeroom management
$41,958	**Annual Total Labor Training Cost**
$77,358	**Total Maintenance Training Cost**

Maintenance Training Cost (per employee) =
Total Maintenance Training Cost / Number of Internal Maintenance Employees

Maintenance Training Cost (per employee) = $77,358 / 22
Maintenance Training Cost (per employee) = $3,516 per employee

Maintenance Training Cost (%) =
(Total Maintenance Training Cost / Total Internal Maintenance Employee Labor Costs) × 100

Maintenance Training Cost (%) = ($77,358 / $1,162,000) × 100
Maintenance Training Cost (%) = 0.066 × 100
Maintenance Training Cost (%) = 6.7%

Training cost for the electricians:

Maintenance Training Cost (for electricians)

$ 0	Safety (completed in-house)
$6,500	Circuit analysis
$1,600	Team building
$8,100	**Annual Maintenance Training Cost (for electricians)**
Labor	
$1,200	Safety
$1,550	Circuit analysis
$ 775	Team building
$3,525	**Annual Total Labor Training Cost (for electricians)**
$11,625	**Total Maintenance Training Cost (for electricians)**

Maintenance Training Cost (by craft or job classification) = Total Maintenance Training Cost (by craft or job classification) / Number of Maintenance Employees (by craft or job classification)

Maintenance Training Cost (for electricians) = $11,625 / 4

Maintenance Training Cost (for electricians) = $2900 per electrician

BEST-IN-CLASS TARGET VALUE

4% of annual wage

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric and its supporting definitions are similar or identical to the indicatorE21 in standard EN15341.

Note 1:The SMRP term: "Maintenance Employees" is similar to EN 15341 "Direct + Indirect personnel".

Note 2: SMRP includes participation in conventions, seminars and workshops under the umbrella of SMRP Body of Knowledge in "training hours."

Note 3: Salary cost during training is included in the calculation.

Note 4: The result of the indicator E21 is "unit of value/person. Metric 4.2.1 offers the possibility to calculate the result as a percentage. This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the E21 indicator.

Additional information is available in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

REFERENCES

Baldwin, R. (2006). Secrets of effective maintenance. Paper presented at S*ociety for Maintenance and Reliability Professionals Annual Conference*, Birmingham, AL. Retrieved from the SMRP Library.

Humphries, J. B. (1998). Best-in-class maintenance benchmarks. *Iron and Steel Engineer*, 1. Mitchell, J. S. (2007). *Physical asset management handbook* (4th ed). South Norwalk, CT: Industrial Press, Inc

ORGANIZATION & LEADERSHIP METRIC

4.2.2 MAINTENANCE TRAINING HOURS

Published on June 14, 2009
Revised on August 12, 2015

DEFINITION

This metric is the number of hours of formal training that maintenance personnel receive annually. It is expressed as hours per employee.

OBJECTIVE

This metric measures the investment in technical training to improve the skills and abilities of maintenance personnel.

FORMULA

Maintenance Training Hours (MTH) = Training Hours (TH) x Number of Maintenance Employees (NME)
MTH = TH x NME

This metric can also be expressed as a percentage of the total number of hours worked by a maintenance department.

Maintenance Training Hours (MTH) =
Training Hours (TH) / Total Maintenance Hours (TMH) x 100
% MTH = TH / TMH x 100

COMPONENT DEFINITIONS

Maintenance Employees
All personnel, salaried and hourly, direct and indirect, who are responsible for executing work assignments pertaining to the maintenance of physical assets and components. Same as internal maintenance employees.

Training Hours
All time spent on formal technical training that is designed to improve job skills. Training provided in a formal setting and typically includes classroom and hands-on training with testing to confirm comprehension. Training can include, but is not limited to, safety, leadership, technical, computer, planning, reliability, problem solving and similar topics. Attendance at conventions, seminars and workshops is credited as training, as long as the subjects fall within the SMRP Body of Knowledge.

QUALIFICATIONS

1. Time basis: Annually
2. This metric is used by maintenance management to measure the investment in skills training.
3. It is used as an aid when evaluating skill levels of maintenance craft personnel.
4. Training should be formal and documented and should include comprehension testing.
5. Individual training needs assessments are important to target specific skills deficiencies and for developing an overall skills training program.
6. It is helpful to break out training by craft or job classification (mechanical, electrical, craft worker, planner, engineer, supervisor, etc.) for benchmarking purposes.
7. This metric may also be expressed as a percentage of total maintenance hours (e.g., Training Hours / Total Maintenance Labor Hours).

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SAMPLE CALCULATION

A given maintenance organization consists of a manager, maintenance engineer, planner, two foremen, 10 mechanics, four electricians and a storeroom clerk. Training hours during the year included:

264 hours	Computerize Maintenance Management System
288 hours	Laser alignment
288 hours	Hydraulic systems
80 hours	Circuit analysis
120 hours	Job planning
176 hours	Team building
52 hours	Mathematics
80 hours	Annual SMRP Conference
72 hours	Storeroom management

Training Hours = 264 + 288 + 288 + 80 + 120 + 176 + 52 + 80 + 72 = 1420 hours
Number of Maintenance Employees = 1 + 1 + 1 + 2 + 10 + 4 + 1 = 20

Maintenance Training Hours =
Training Hours / Number of Maintenance Employees

Maintenance Training Hours = 1420 hours / 20 Maintenance Employees
Maintenance Training Hours = 71 hours/employee

Training Hours as a Percentage of Total Maintenance Hours

The maintenance department total hours for the year were 38,400 man hours.
Maintenance Training Hours (%) = (Training Hours / Total Hours Worked) × 100
Maintenance Training Hours (%) = (1420 hours / 38,400 hours) × 100
Maintenance Training Hours (%) = 0.037 × 100
Maintenance Training Hours (%) = 3.7%

Training Hours by Craft

The four electricians received the following training:

48 hours	Computerize Maintenance Management System
64 hours	Circuit analysis
32 hours	Team building

The total hours of electrician training for the year = 48 + 64 + 32 = 144 hours
Maintenance Training Hours = 144 hours/4 electricians
Maintenance Training Hours = 36 hours/electrician

BEST-IN-CLASS TARGET VALUE

80 hours per year

CAUTIONS

This metric does not include annual or regulatory safety training. This training should be tracked separately.

HARMONIZATION

This metric and its supporting definitions are similar or identical to EN 15341 indicator O23.

Note 1: The difference between the SMRP metric and EN15341 indicator O23 is in the calculation method. EN 15341 Indicator O23 expresses the result as a percentage. SMRP Metric 4.2.2 metric calculates the result as hours per year per maintenance employee.

Note 2: The denominator is similar for both metrics, including training hours for direct and indirect personnel. EN15341 O23 expresses the indicator as a percentage of "total maintenance personnel man hours" which includes contractor hours and excludes indirect personnel.

Note 3: The SMRP term "maintenance employees" is similar to EN 15341 "direct + indirect personnel".

Note 4: SMRP includes participation in conventions, seminars and workshops under the umbrella of SMRP Body of Knowledge in "training hours". This difference is estimated to impact the calculation with less than 5%.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the O23 indicator. Additional information is available in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

REFERENCES

Panel Discussion. (2005). Maintenance & Reliability Technology Summit (MARTS): *Best practices, Key Performance Indicators*. Chicago, IL: MARTS.

Mitchell, J. S. (2007). *Physical Asset Management Handbook* (4th ed). South Norwalk, CT: Industrial Press, Inc.

Humphries, J. B. (1998). *Best-in-Class Maintenance Benchmarks*. Iron and Steel Engineer, 1.

ORGANIZATION & LEADERSHIP METRIC

4.2.3 MAINTENANCE TRAINING RETURN ON INVESTMENT (ROI)

Published on April 16, 2009

DEFINITION

This metric is the ratio of the benefit to the cost of training internal maintenance employees.

OBJECTIVES

The objective of this metric is to determine the return on investment of training of maintenance employees. It can be utilized to justify the investment in training in order to garner approval from management.

FORMULA

Maintenance Training ROI (%) = [Business Benefits ($) / Training Cost ($)] × 100

COMPONENT DEFINITIONS

Business Benefits

The financial benefits that impact the business, such as increases in worker productivity, improved work quality, reduced injuries and incidents and other related direct cost savings caused by an investment in training maintenance employees. Benefits must be translated into a cost benefit.

Internal Maintenance Employees

All personnel, salaried and hourly, direct and indirect, who are responsible for executing work assignments pertaining to the maintenance of physical assets and components. Same as maintenance employees.

Maintenance Employees

All personnel, salaried and hourly, direct and indirect, who are responsible for executing work assignments pertaining to the maintenance of physical assets and components. Same as internal maintenance employees.

Total Maintenance Training Cost
The sum of all costs for formal training that is directed at improving job skills for maintenance employees. Training cost should include all employee labor, travel expenses, materials, registration fees, instructor fees, etc.

QUALIFICATIONS

1. Time basis: Annually
2. This metric is used by maintenance managers to justify the investment in maintenance training.
3. Measurements should be made before and after the training to determine the benefits derived from the training.
4. Specific and measurable objectives should be established for maintenance training.
5. Maintenance training ROI is not an effective metric to capture the impact on broad averages (e.g., mean time between failures (MTB), mean time to repair (MTTR), etc.)
6. A training needs assessment can be used to identify and prioritize maintenance training needs.
7. A training needs assessment can also be used to estimate the cost-benefit of specific trainings needs.
8. Additional training needs may be found by analyzing job plans, work history, failure codes, etc.
9. The benefits of soft skills (e.g., team work, worker empowerment, etc.) training are more difficult to measure.

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SAMPLE CALCULATION

A given plant trained 20 maintenance employees on the use of handheld vibration analyzers. The Maintenance Training ROI calculation for the two-day maintenance training session is reflected below.

Total Maintenance Training Cost

Individual maintenance employee wage (labor + burden) = $35/hr × 16 hrs = $560 per maintenance employee
Total maintenance employee wages = $560 per maintenance employee × 20
Maintenance employees = $11,200
Training materials for 20 maintenance employees = $2,000
Trainer's cost (provided by vibration analyzer vendor) = $0
Total Maintenance Training Cost = $11,200 + $2,000 = $13,200

Business Benefits

Before and after metrics indicated that the vibration analysis skills learned by the mechanics during the two-day training session resulted in avoiding 13 unplanned equipment failures that saved $23,420 in reactive maintenance costs (beyond the planned maintenance costs) and the avoidance of $215,000 in lost margin due to production interruptions. The use of the handheld vibration analyzers reduced repair times significantly and increased plant uptime and profitability. The total business benefit derived from the training was $238,420 ($23,420 + $215,000).

Maintenance Training ROI (%) = [{Business Benefits ($) / Training Cost ($)] × 100

Maintenance Training ROI (%) = ($238,420 / $13,200) × 100
Maintenance Training ROI (%) = 18.06 × 100
Maintenance Training ROI (%) = 1,806%

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee was unable to find any target ranges, minimum/maximum values, benchmarks or other references for target values for this metric. SMRP will update this metric as appropriate should future work help establish targets for this metric. While no target values are currently available, SMRP encourages plants to use this metric to help manage the maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Approved by consensus of SMRP Best Practice Committee.

Pillar 5
Work Management

MAINTENANCE & RELIABILITY BODY OF KNOWLEDGE

SMRP
Society for Maintenance & Reliability Professionals

WORK MANAGEMENT METRIC

5.1.1 CORRECTIVE MAINTENANCE COST

Published on April 16, 2009
Revised on August 16, 2016

DEFINITION

This metric is the percentage of total maintenance cost that is used to restore equipment to a functional state after a failure or when failure is imminent. See Figure 1.

OBJECTIVES

This metric quantifies the financial impact of work done on corrective maintenance tasks. Trending corrective maintenance costs can provide feedback to evaluate the effectiveness of proactive activities.

FORMULA

Corrective Maintenance Cost (%) =
((Total Corrective Maintenance Cost ×100) / Total Maintenance Cost))

COMPONENT DEFINITIONS

Corrective Maintenance Costs

The labor, material, services and/or contractor cost for work done to restore the function of an asset after failure or when failure is imminent. Includes operator costs if all operator maintenance costs are included in total maintenance cost.

Total Maintenance Cost

The total expenditures for maintenance labor, including maintenance performed by operators such as total productive maintenance (TPM), materials, contractors, services and resources. Includes all maintenance expenses for outages, shutdowns or turnarounds, as well as normal operating times. Also includes capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include capital expenditures for plant expansions or improvements.

QUALIFICATIONS

1. Time Basis: Monthly
2. This metric is used by maintenance management personnel to evaluate the effectiveness of proactive activities, such as preventive and predictive maintenance programs.
3. To obtain data necessary for this measure, the work order system must be configured so that corrective maintenance work is differentiated from other types of work. This can usually be done by setting up the appropriate work types and classifying each work order accordingly.
4. The costs incurred for corrective work resulting from problems discovered before failure (e.g., predictive maintenance inspections) should be included in corrective maintenance cost.
5. A high percentage of corrective maintenance cost is typically an indication of a reactive work culture and poor asset reliability. It can also indicate ineffective preventive and predictive maintenance programs.

SAMPLE CALCULATION

The total maintenance cost for the month was $1,287,345. The total cost of all corrective work orders was $817,010.

Corrective Maintenance Cost (%) =
Corrective Maintenance Cost ×100) / Total Maintenance Cost

Corrective Maintenance Cost (%) = ($817,000 ×100) / $1,287,345
Corrective Maintenance Cost (%) = $81,700,000 / $1,287,345
Corrective Maintenance Cost (%) = 63.5%

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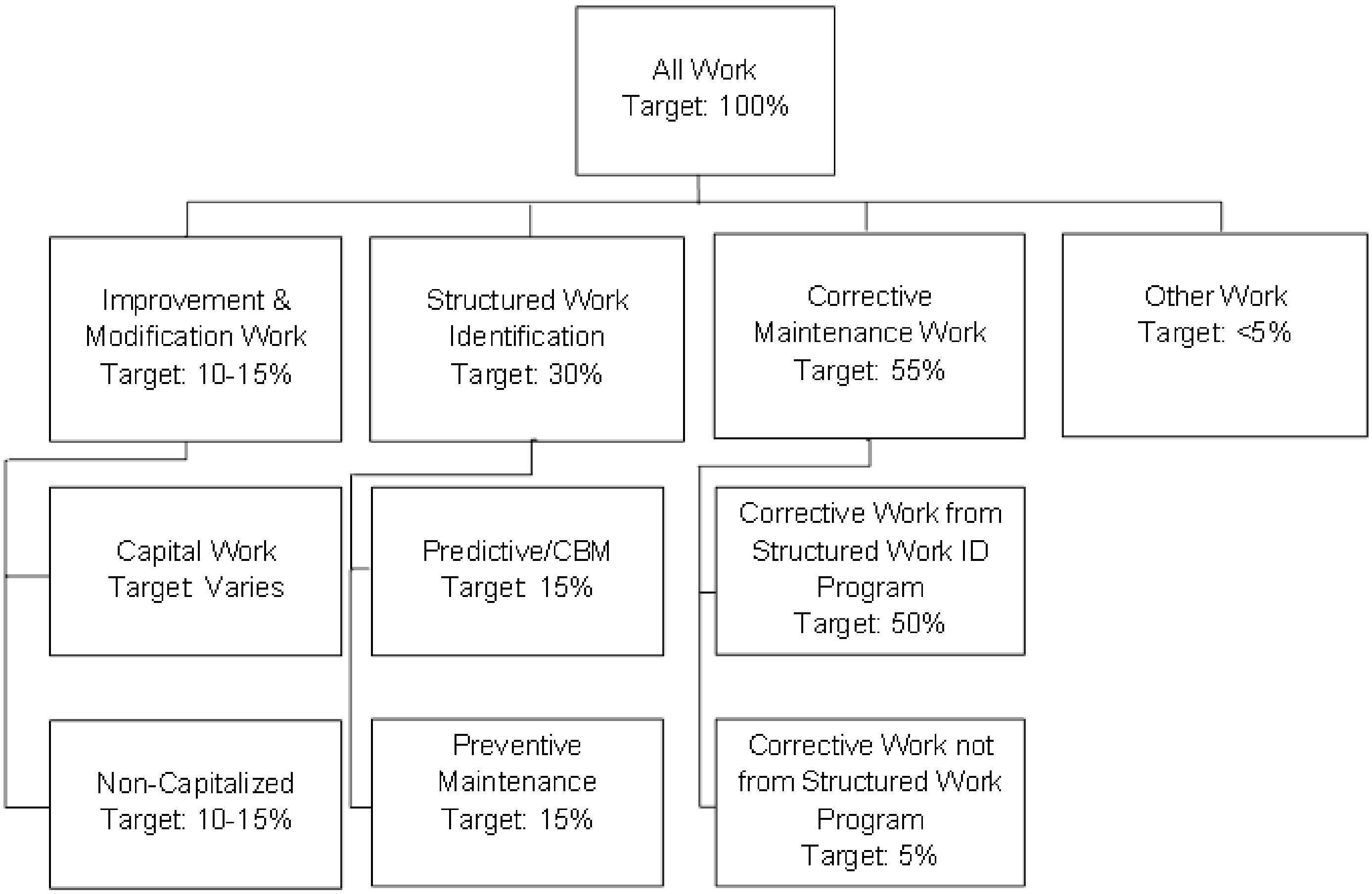

Figure 1. Maintenance Work Types

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee was unable to find any target ranges, minimum/maximum values, benchmarks or other references to target values for this metric. SMRP will update this metric as appropriate should future work help establish targets for this metric. While no current target values are available, SMRP encourages plants to use this metric to help manage the maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs. It is strongly encouraged to review the best-in-class target value for the related SMRP Metric 5.1.2.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric and its supporting definitions are similar to the indicator E15 in standard EN 15341.

Note 1: The difference between this SMRP metric and E15 in standard EN 15341 is that EN 15341 has a broader definition and includes depreciation of maintenance owned equipment and facilities in "total maintenance cost" (office, workshop and warehouse)

Note 2: The SMRP component definition for corrective maintenance "is the hours/cost to restore equipment to a functional state after a failure or when a failure is imminent." This is similar to the EN 13306 definition "maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function."

Note 3: Corrective maintenance consists of "deferred maintenance" and "immediate/breakdown maintenance."

Note 4: SMRP includes part of the work identified during condition based maintenance (CBM), and preventive maintenance (PM) in the corrective maintenance definition.
In the EN definition for condition based maintenance, any work identified during CBM activities is included in CBM indicators.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the E15 indicator. Additional information is available in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

REFERENCES

Approved by consensus of SMRP Best Practice Committee.

WORK MANAGEMENT METRIC

5.1.2 CORRECTIVE MAINTENANCE HOURS

Published on June 27, 2009
Revised on August 16, 2016

DEFINITION

This metric is the percentage of total maintenance labor that is used to restore equipment to a functional state after a failure-finding task indicated a functional failure or when functional failure is imminent or has already occurred. See Figure 1.

OBJECTIVES

This metric quantifies the labor resource impact of work done on corrective maintenance tasks. Trending corrective maintenance hours can provide feedback to evaluate the effectiveness of proactive activities.

FORMULA

Corrective Maintenance Hours (%) =
(Corrective Maintenance Hours × 100) / Total Maintenance Labor Hours

COMPONENT DEFINITIONS

Corrective Maintenance Labor Hours
The labor hours are the labor hours used to restore the function of an asset after failure or when failure is imminent. Labor can be internal and/or external (contract).

Total Maintenance Labor Hours
Expressed in hours and includes all maintenance labor hours for normal operating times as well as outages, shutdowns and turnarounds. If operator hours spent on maintenance activities are captured, they should be included in the numerator and denominator of all applicable metrics. Include labor hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include labor hours used for capital expansions or improvements. Typically, total maintenance labor hours do not include temporary contractor labor hours.

QUALIFICATIONS

1. Time Basis: Monthly
2. This metric is used by maintenance management personnel to evaluate the effectiveness of proactive activities, such as preventive and predictive maintenance programs.
3. To obtain data necessary for this measure, the work order system must be configured so that corrective maintenance work is differentiated from other types of work. This can usually be done by setting up the appropriate work types and classifying each work order accordingly.
4. The labor incurred for corrective work resulting from problems discovered before failure (e.g., predictive maintenance inspections) should be included in corrective maintenance labor hours.
5. A high percentage of corrective maintenance labor hours could be an indication of a reactive work culture and poor asset reliability.

SAMPLE CALCULATION

The total internal maintenance labor used during the month was 2,400 hours of straight time and 384 hours of overtime. Maintenance done by contractors consumed another 480 hours. Corrective maintenance labor during the month was 1,832 hours.

Corrective Maintenance Hours (%) =
(Corrective Maintenance Hours × 100) / Total Maintenance Labor Hours)

Corrective Maintenance Hours (%) = [1832 / (2400 + 384 + 480)] × 100
Corrective Maintenance Hours (%) = (1832 / 3264) × 100
Corrective Maintenance Hours (%) = 0.561 × 100
Corrective Maintenance Hours (%) = 56.1%

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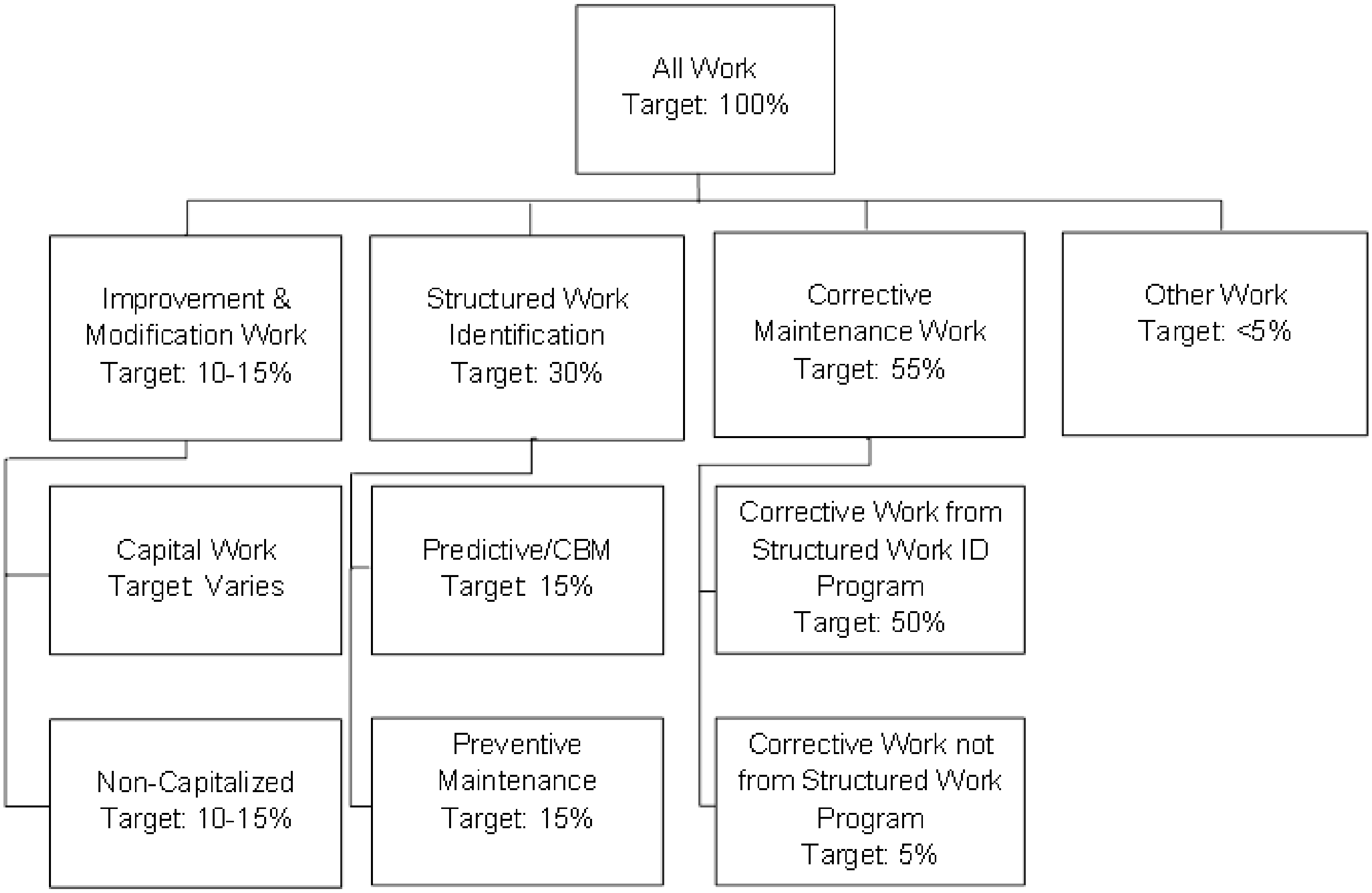

Figure 1. Maintenance Work Types

BEST-IN-CLASS TARGET VALUE

The SMRP Best Practices Committee recommends a target of 55% for this metric, broken down as follows:

- Corrective maintenance hours derived from preventive maintenance inspections (a subset of corrective maintenance hours) is generally agreed to be 15% of total maintenance labor hours.
- Corrective maintenance hours derived from predictive maintenance inspections (a subset of corrective maintenance hours) is generally agreed to be 35% of total maintenance labor hours.

- Corrective maintenance hours derived from labor hours spent restoring equipment to functional health after failure has already occurred (a subset of corrective maintenance hours) is generally agreed to be <5% of total maintenance labor hours.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

EN 15341 Indicator O16 and SMRP Metric 5.1.2 are Similar

Note 1: The SMRP component definition for corrective maintenance "is the hours/cost to restore equipment to a functional state after a failure or when a failure is imminent." This is similar to the EN 13306 definition, "maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function."

Note 2: Corrective maintenance consists of "deferred maintenance" and "immediate/breakdown maintenance."

Note 3: SMRP includes part of work identified during condition based maintenance (CBM) and preventive maintenance (PM) in the corrective maintenance definition. In the EN definition for condition based maintenance any work identified during CBM activities is included in the CBM indicators.

Depending on the application of the metric, one should be careful about making comparisons.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the O16 indicator. Additional information is available in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

REFERENCES

DiStefano, R. (2005, January). Unlocking Big Benefits. Uptime.

WORK MANAGEMENT METRIC

5.1.3 PREVENTIVE MAINTENANCE (PM)

Published on April 16, 2009
Revised on August 16, 2016

DEFINITION

This metric is the maintenance cost that is used to perform fixed interval maintenance tasks, regardless of the equipment condition at the time. The result is expressed as a percentage of total maintenance costs. See Figure 1.

OBJECTIVES

The objective of this metric is to quantify the financial impact of work done as preventive maintenance tasks. Trending the percentage of preventive maintenance costs can provide feedback to evaluate the effectiveness of proactive activities when compared to the percentage of cost trends of all maintenance work types.

FORMULA

Preventive Maintenance Cost (%) =
[Preventive Maintenance Cost ($) / Total Maintenance Cost ($)] × 100

COMPONENT DEFINITIONS

Preventive Maintenance (PM)
Actions performed on a time- or machine-run-based schedule that detect, preclude or mitigate degradation of a component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level.

Preventive Maintenance Cost
The labor, material and services cost, including maintenance performed by operators (e.g., total productive maintenance (TPM), by company personnel or contractors for work performed as preventive maintenance. Includes operator costs if all operator maintenance costs are included in total maintenance cost.

Total Maintenance Cost
The total expenditures for maintenance labor, including maintenance performed by operators such as total productive maintenance (TPM), materials, contractors, services and resources. Includes all maintenance expenses for outages, shutdowns or turnarounds, as well as normal operating times. Also includes capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include capital expenditures for plant expansions or improvements.

QUALIFICATIONS

1. Time basis: Monthly
2. This metric is used by maintenance and reliability personnel.
3. It provides the best data when used to evaluate the effectiveness of proactive maintenance and reliability activities when compared to other maintenance work types.
4. This metric can also be an indicator of preventive maintenance efficiency and PM leveling when PM task counts remain constant over time.
5. To obtain data necessary for this measure, the work order system must be configured in such a way that preventive maintenance work can be differentiated from other work types. This can usually be done by setting up appropriate work types and classifying each work order accordingly.
6. The cost incurred for preventive maintenance work and minor adjustments or corrections while completing the scheduled interval tasks, and performed under the same work order, should be included in preventive spending.
7. Time completing PM tasks should not be extended much beyond the normal required time to complete minor corrections.
8. Hours for work done offsite is much more difficult to track and is not normally included.
9. Failure finding tasks for hidden failures carried out on a scheduled interval are considered condition based maintenance.
10. If operator maintenance costs are included in total maintenance cost, they should be included in preventive maintenance cost.

SAMPLE CALCULATION

A given plant has the total maintenance cost for the month of $567,345. The total cost of preventive work orders was $227,563. Contractor preventive work totaled $23,578. Operator preventive work orders totaled $7,300.

Preventive Maintenance Cost (%) =
[Preventive Maintenance Cost ($) / Total Maintenance Cost ($)] × 100

Preventive Maintenance Cost (%) =
[($227,563 + $23,587 +$7,300) / $567,345] × 100

Preventive Maintenance Cost (%) = ($258,450 / $567,345] × 100

Preventive Maintenance Cost (%) = 0.456 × 100

Preventive Maintenance Cost (%) = 45.6%

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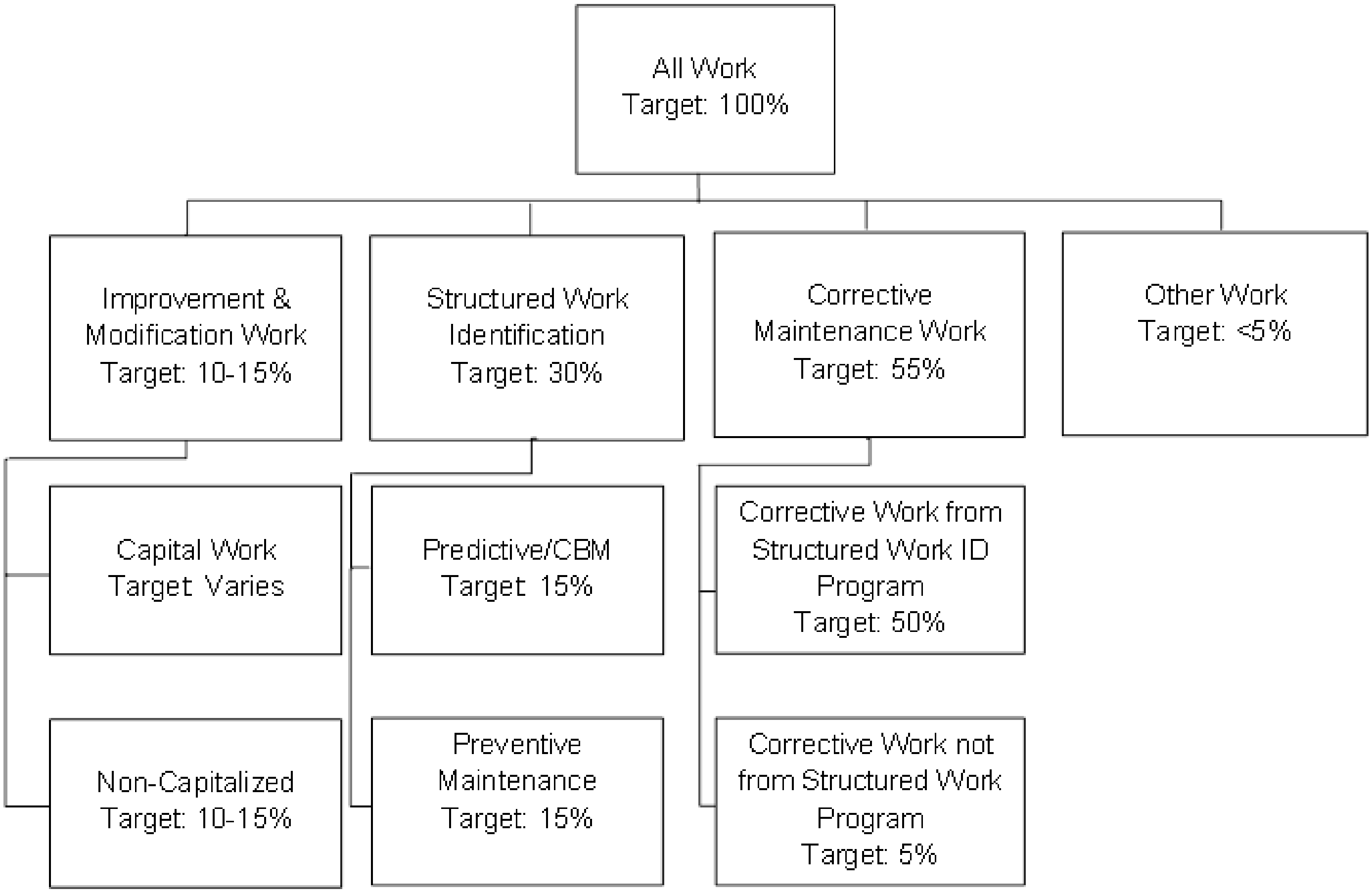

Figure 1. Maintenance Work Types

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee does not recommend a target range, minimum/maximum values or benchmarks for this metric. SMRP will update this document as appropriate should future work help establish targets for this metric. This metric is however in direct relationship to the preventive maintenance hour metric, 5.1.4, which does have a best-in-class target. Several discussions on maintenance hours suggest the level of preventive maintenance activities, and this metric should track in direct relationship to the level of preventive maintenance hours.

Preventive maintenance cost is dependent on the age, type, complexity, industry and technology of the assets maintained. SMRP encourages plants to use this metric to help evaluate the preventive maintenance program. Trending of this metric can quickly assess the health of a program by gauging the increase or decrease of the PM cost ratio when the level of PM activity trend remains constant.

CAUTIONS

The time basis for this metric must be established and applied consistently when comparing or trending this value for analysis. The work order system must be configured in such a way that preventive maintenance work can be differentiated from other work types.

HARMONIZATION

This metric and its supporting definitions are similar to the indicator E18 in standard EN15341.

Note 1: The difference between this SMRP metric and the indicator E18 in standard EN15341 is that EN 15341 has a broader definition and includes depreciation of maintenance owned equipment and facilities in "total maintenance cost" (office, workshop and warehouse).

Note 2: The SMRP term "preventive" = The EN 13306/15341term "predetermined."

Note 3: Minor tasks not included in the preventive/predetermined procedure detected during preventive/predetermined maintenance are included in preventive/predetermined activities.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the E18 indicator. Details are provided in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

REFERENCES

Call, R. (2007). Analyzing the relationship of preventive maintenance to corrective maintenance. *Maintenance Technology*, 20 (6).

Mitchell, J. S. (2007). *Physical asset management handbook* (4th ed). South Norwalk, CT: Industrial Press, Inc.

Schultz, J. and DiStefano, R. (2003). *The business case for reliability*. Presented at the 18th International Maintenance Conference. Fort Myers, FL: NetexpressUSA, Inc.

Taylor, J. (2000 - 2008). *Five steps to optimizing your preventive maintenance system.* Retrieved from http://www.reliabilityweb.com

Van Hoy, T. and Koo, W. L. (2000). Determining the economic value of preventive maintenance. Chicago, IL: Jones Lang LaSalle.

WORK MANAGEMENT METRIC

5.1.4 PREVENTIVE MAINTENANCE (PM) HOURS

Published on January 28, 2010
Revised on August 16, 2016

DEFINITION

This metric is the percentage of maintenance labor hours used to perform fixed interval maintenance tasks, regardless of the equipment condition at the time. See Figure 1.

OBJECTIVES

The objective of this metric is to quantify the labor resource impact of work done on preventive maintenance tasks. Trending the percentage of preventive maintenance hours can provide feedback to evaluate the quantity of preventive activities when compared to the percentage of labor hour trends of all maintenance work types.

FORMULA

Preventive Maintenance Hours (%) =
(Preventive Maintenance Hours / Total Maintenance Labor Hours) × 100

COMPONENT DEFINITIONS

Preventive Maintenance (PM)
Actions performed on a time- or machine-run-based schedule that detect, preclude or mitigate degradation of a component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level.

Preventive Maintenance Labor Hours
The maintenance labor hours to replace or restore an asset at a fixed interval regardless of its condition. Scheduled restoration and replacement tasks are examples of preventive maintenance.

Total Maintenance Labor Hours
Expressed in hours and includes all maintenance labor hours for normal operating times as well as outages, shutdowns and turnarounds. If operator hours spent on maintenance activities are

captured, they should be included in the numerator and denominator of all applicable metrics. Include labor hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include labor hours used for capital expansions or improvements. Typically, total maintenance labor hours do not include temporary contractor labor hours.

QUALIFICATIONS

1. Time basis: Monthly
2. This metric is used by maintenance and reliability personnel.
3. It provides the best data when used for evaluating the effectiveness of proactive maintenance and reliability activities when compared to other maintenance work types (e.g., corrective maintenance).
4. This metric can also be an indicator of PM efficiency and PM leveling when PM tasks remain constant over time.
5. The work order system must be configured in such a way that preventive maintenance work can be differentiated from other work types. This can usually be done by setting up appropriate work types and classifying each work order accordingly.
6. The hours incurred for preventive maintenance work and minor adjustments or corrections while completing the scheduled interval tasks and performed under the same work order should be included in the preventive hours.
7. Time spent for minor corrections would not extend much beyond the time allowed for PM.
8. Hours for work done offsite is much more difficult to track and is not normally included.
9. Failure finding tasks carried out at a scheduled interval are considered condition based maintenance.
10. If operator maintenance hours are included in total maintenance labor hours, they should be included in preventive maintenance hours.

SAMPLE CALCULATION

A given plant has total maintenance hours for the month of 1,800 hours of straight time and 125 hours of overtime. The monthly scheduled operator rounds of lubrication, filter changes, burner cleanings and adjustments consumed another 150 hours. The total hours from preventive work orders totaled 452 hours.

Preventive Maintenance Hours (%) =
(Preventive Maintenance Hours / Total Maintenance Labor Hours) × 100

Preventive Maintenance Hours (%) = [452 hours / (1800 + 125 + 150)] × 100
Preventive Maintenance Hours (%) = (452 hours / 2075) × 100
Preventive Maintenance Hours (%) = 0.218 × 100
Preventive Maintenance Hours (%) = 21.8%

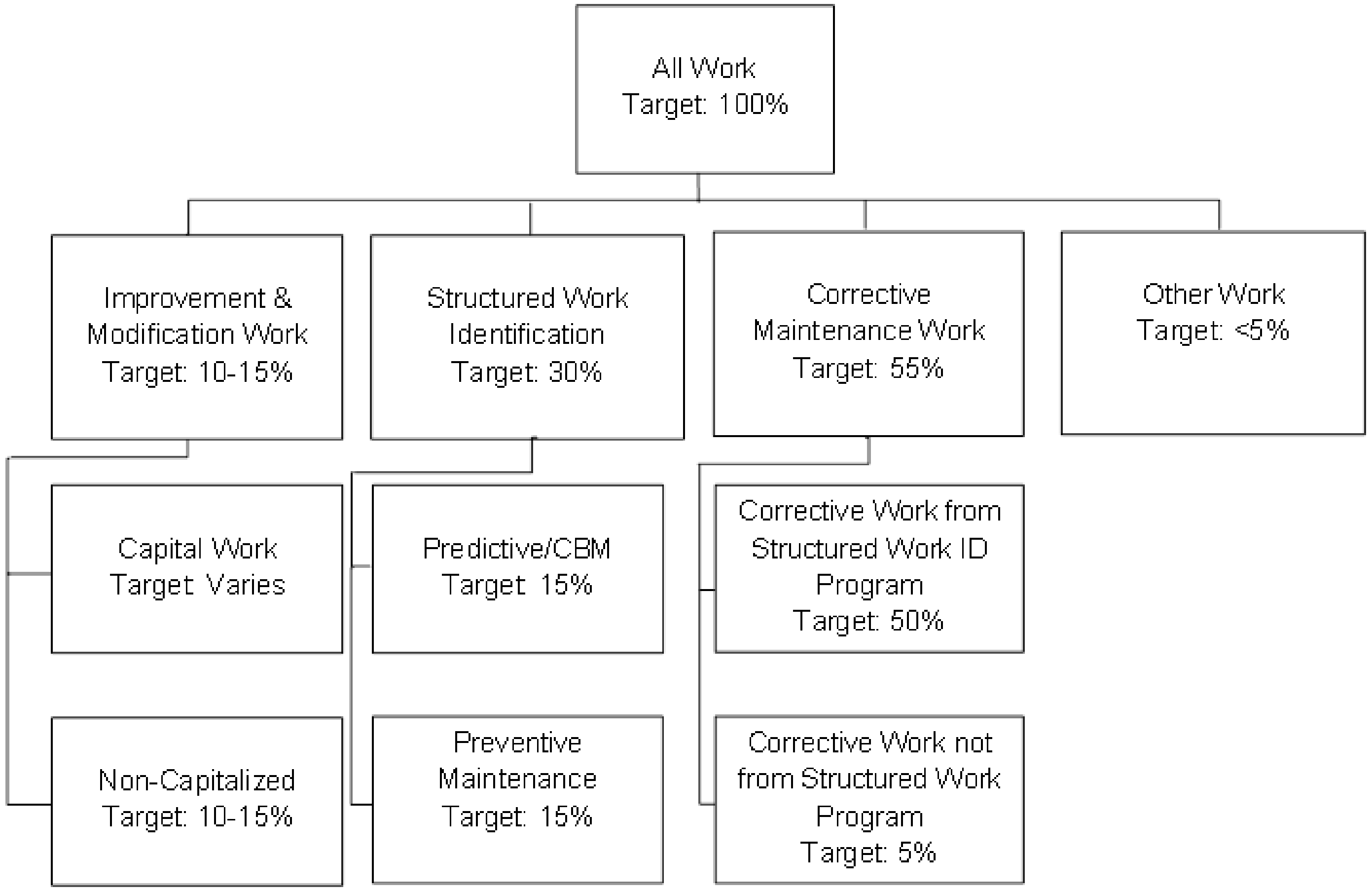

Figure 1. Maintenance Work Type

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee recommends a target of 15% of all maintenance hours. A lower value is achievable and acceptable for newer, technically advanced equipment or processes and when supported by a robust condition based maintenance program. A higher value is acceptable for older assets where condition base techniques may not be an available practice. We encourage this metric to be monitored in conjunction with SMRP Metric 5.1.3 for further evaluation of the preventive maintenance program. Preventive maintenance hours is influenced by the age, type, complexity, industry and technology of the assets maintained.

CAUTIONS

The time basis for this metric must be established and applied consistently when comparing or trending this value for analysis. The work order system must be configured in such a way that preventive maintenance work can be differentiated from other work types.

HARMONIZATION

This metric and its supporting definitions are similar or identical to the indicator O20 in standardEN15341.

Note 1: SMRP "preventive" = EN 13306/15341 "predetermined."

Note 2: Minor tasks not included in the procedure detected during preventive/predetermined maintenance are included in preventive/predetermined activities.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the O20 Indicator. Details are provided in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

REFERENCES

Call, R. (2007). Analyzing the relationship of preventive maintenance to corrective maintenance. *Maintenance Technology*, 20 (6).

Mitchell, J. S. (2007). *Physical asset management handbook* (4th ed). South Norwalk, CT: Industrial Press, Inc.

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Taylor, J. (2000 - 2008). *Five steps to optimizing your preventive maintenance system.* Retrieved from http://www.reliabilityweb.com

Van Hoy, T. and Koo, W. L. (2000). Determining the economic value of preventive maintenance. Chicago, IL: Jones Lang LaSalle.

WORK MANAGEMENT METRIC

5.1.5 CONDITION BASED MAINTENANCE COST

Published April 16, 2009

DEFINITION

This metric is the percentage of maintenance labor hours used to measure, trend and compare equipment conditions against known standards to detect, analyze and correct problems before they cause functional failures. See Figure 1.

OBJECTIVES

The objective of this metric is to track cost of condition based (predictive) maintenance tasks. Trending the percentage of condition based maintenance cost can provide feedback to evaluate the effectiveness of proactive activities when compared to the percentage of cost of all maintenance work types.

FORMULA

Condition Based Maintenance Cost (%) =
[Condition Based Maintenance Cost ($) / Total Maintenance Cost ($)] × 100

COMPONENT DEFINITIONS

Condition Based Maintenance

An equipment maintenance strategy based on measuring the condition of equipment against known standards in order to assess whether it will fail during some future period and taking appropriate action to avoid the consequences of that failure. The condition of the equipment could be measured using condition monitoring, statistical process control, equipment performance or through the use of human senses. The terms condition based maintenance (CBM), on-condition maintenance and predictive maintenance (PdM) can be used interchangeably.

Condition Based Maintenance Cost

The cost that is used to measure the condition of equipment against known standards in order to assess whether it will fail during some future period.

Total Maintenance Cost
The total expenditures for maintenance labor, including maintenance performed by operators such as total productive maintenance (TPM), materials, contractors, services and resources. Includes all maintenance expenses for outages, shutdowns or turnarounds, as well as normal operating times. Also includes capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include capital expenditures for plant expansions or improvements.

QUALIFICATIONS

1. Time basis: Monthly
2. This metric is used by maintenance and reliability personnel.
3. CBM maintenance cost provides the best data when used to evaluate the effectiveness of proactive maintenance and reliability activities compared to other maintenance work types (e.g., corrective maintenance).
4. The work order system must be configured in such a way that condition based maintenance work can be differentiated from other types of work. This can usually be done by setting up appropriate work types and classifying each work order accordingly.
5. The costs incurred for condition based maintenance work and minor adjustments or corrections while completing the monitoring tasks, and performed under the same work order, should be included in the condition based cost.
6. Time spent for minor corrections should not extend much beyond the time allowed for the CBM.
7. Failure finding tasks carried out at a scheduled interval are considered condition based maintenance.
8. If operator maintenance costs are included in total maintenance cost, they should be included in condition based maintenance cost.

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SAMPLE CALCULATION

A given plant has a total maintenance cost for the month of $194,400. The total cost of predictive work orders was $17,100. Contractor predictive work totaled $9,300. Operator work orders for equipment monitoring totaled $4,898.

Condition Based Maintenance Cost (%) =
[Condition Based Maintenance Cost ($) / Total Maintenance Cost ($)] × 100

Condition Based Maintenance Cost (%) =
[($17,100 + $9,300+$4898) / $193,400] × 100
Condition Based Maintenance Cost (%) = ($31,298 / $193,400) × 100
Condition Based Maintenance Cost (%) = 0.162 × 100
Condition Based Maintenance Cost (%) = 16.2 %

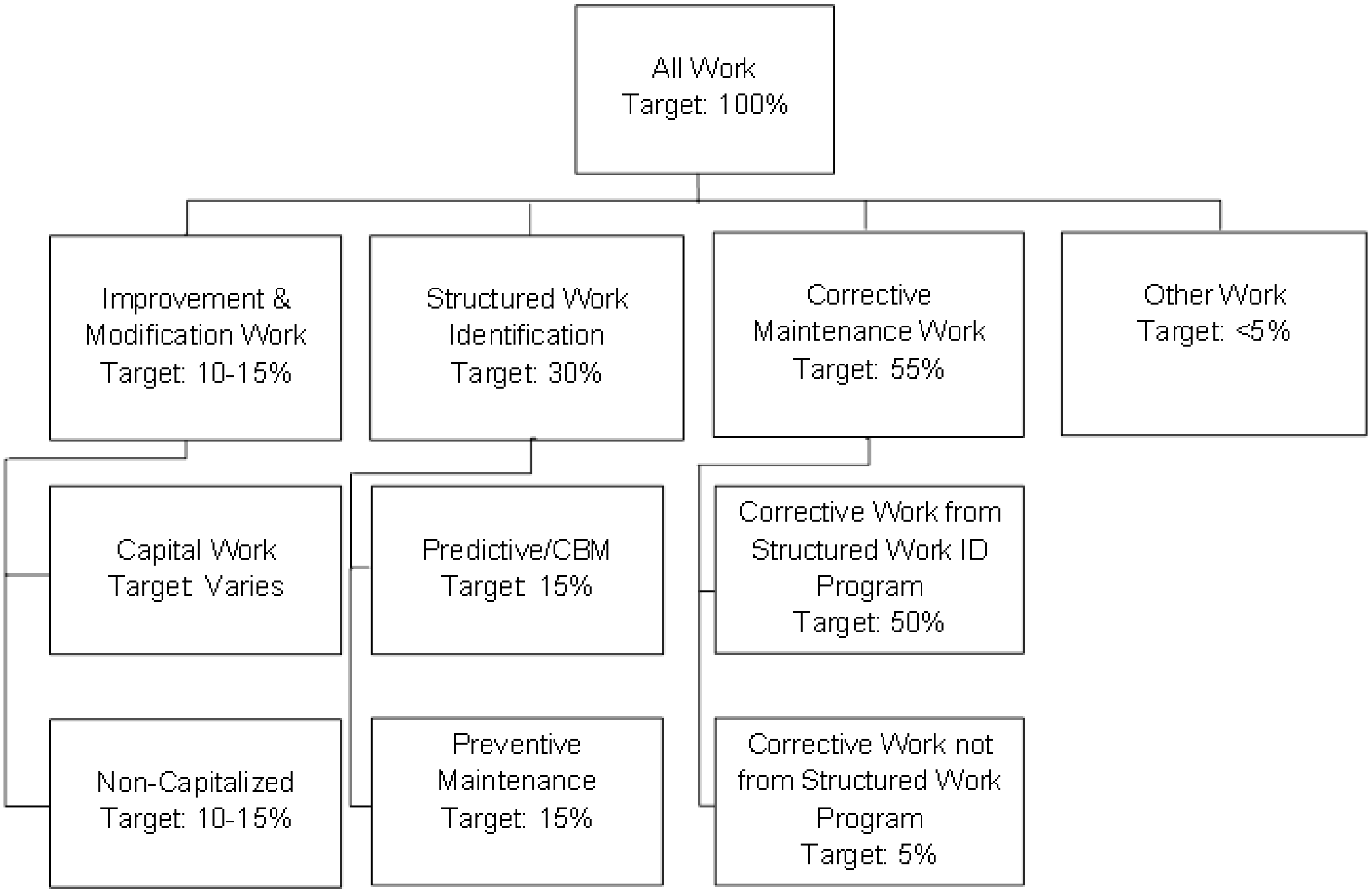

Figure 1. Maintenance Work Types

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee does not recommend a target range, minimum/maximum values or benchmarks for this metric. SMRP will update this document as appropriate should future work help establish targets for this metric. This metric is, however, in direct relationship to SMRP Metric 5.1.6. Several discussions on maintenance hours suggest the level of condition based maintenance activities, and this metric should track in direct relationship to the level of condition based maintenance hours. Condition based maintenance cost is dependent on the age, type, complexity, industry and technology of the assets maintained. SMRP encourages plants to use this metric to help evaluate the condition based maintenance program. Trending of this metric can quickly assess the health of a program by gauging the increase or decrease of the PdM cost ratio when the level of PdM activity trend remains constant.

CAUTIONS

The time basis for this metric must be established and applied consistently when comparing or trending this value for analysis. The work order system must be configured in such a way that condition based maintenance work can be differentiated from other work types.

HARMONIZATION

This metric and its supporting definitions are similar or identical to the indicator E17 in standard EN15341.

Note 1: The difference between this SMRP metric and the indicator E17 in standard EN15341 is that EN 15341 has a broader definition and includes depreciation of maintenance owned equipment and facilities in "total maintenance cost" (e.g. office, workshop and warehouse).

Note 2: EN 15341 defines Conditioned Maintenance (cost) as: "Preventive maintenance which includes a combination of condition monitoring and/or inspection and/or testing analysis and the following maintenance actions." SMRP counts the "condition monitoring and/or inspection and/or testing analysis" and does not include the ensuing activities (e.g. work performed as corrective maintenance) as CBM.

Conclusion: Calculating the indicator based on the SMRP Metric 5.1.5 definition will give a lower number than by the EN 15341 definition since the ensuing actions are excluded from the SMRP definition of CBM.

Note 3: Both EFNMS and SMRP include human senses in CBM.

Note 4: Both EFNMS and SMRP include failure finding tasks for hidden failures in CBM ref. IEC 60300-3-11.

Note 5: EN 15341 and SMRP include operator CBM hours in the calculation.
This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating theE17 indicator. Details are provided in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

REFERENCES

Mitchell, J. (2002). *Physical Asset Management Handbook* (3rd Ed). Houston, TX. Clarion Technical Publishers.

Schultz, J. and DiStefano, R. (2003). *The Business Case for Reliability*. Presented at the 18th International Maintenance Conference*.* Fort Myers, FL: NetexpressUSA, Inc.

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Wireman Terry Wireman (2004). *Benchmarking Best Practices in Maintenance Management.* New York, NY: Industrial Press, Inc.

WORK MANAGEMENT METRIC

5.1.6 CONDITION BASED MAINTENANCE HOURS

Published on April 16, 2009
Revised on August 16, 2016

DEFINITION

This metric is the percentage of maintenance labor hours used to measure, trend and compare equipment conditions against known standards to detect, analyze and correct problems before they cause functional failures. See Figure 1.

OBJECTIVES

The objective of this metric is to quantify the labor resource impact of work done as condition based (predictive) maintenance tasks. Trending the percentage of condition based maintenance hours can provide feedback to evaluate the quantity of proactive activities when compared to the percentage of labor hour trends of all maintenance work types.

FORMULA

Condition Based Maintenance Hours (%) =
(Condition Based Maintenance Labor Hours / Total Maintenance Labor Hours) × 100

COMPONENT DEFINITIONS

Condition Based Maintenance
An equipment maintenance strategy based on measuring the condition of equipment against known standards in order to assess whether it will fail during some future period and taking appropriate action to avoid the consequences of that failure. The condition of the equipment could be measured using condition monitoring, statistical process control, equipment performance or through the use of human senses. The terms condition based maintenance (CBM), on-condition maintenance and predictive maintenance (PdM) can be used interchangeably.

Condition Based Maintenance Hours
The percentage of maintenance labor hours used to measure, trend and compare equipment conditions to detect, analyze and correct problems before they cause functional failures.

Condition Based Maintenance Labor Hours
The maintenance labor hours used to measure, trend and compare equipment conditions against known standards to detect, analyze and correct problems before they cause functional failures.

Total Maintenance Labor Hours
Expressed in hours and includes all maintenance labor hours for normal operating times as well as outages, shutdowns and turnarounds. If operator hours spent on maintenance activities are captured, they should be included in the numerator and denominator of all applicable metrics. Include labor hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include labor hours used for capital expansions or improvements. Typically, total maintenance labor hours do not include temporary contractor labor hours.

QUALIFICATIONS

1. Time basis: Monthly
2. This metric is used by maintenance and reliability personnel.
3. Condition based maintenance hours provide the best data when used for evaluating the effectiveness of proactive maintenance and reliability activities when compared to other maintenance work types (e.g., corrective maintenance).
4. It can also be an indicator of condition based maintenance efficiency and CBM leveling when CBM tasks remain constant over time.
5. The work order system must be configured in such a way that CBM work can be differentiated from other work types. This can usually be done by setting up appropriate work types and classifying each work order accordingly.
6. The hours incurred for condition based maintenance work and minor adjustments or corrections while completing the monitoring tasks, and performed under the same work order, should be included in condition based maintenance hours. Time spent for minor corrections would not extend beyond the time allowed for the CBM.
7. Hours for work done offsite are much more difficult to track and are not normally included.
8. Failure finding tasks carried out at a scheduled interval are considered Condition Based Maintenance.

9. This metric includes operator hours if all operator maintenance hours are included in total maintenance labor hours.

SAMPLE CALCULATION

A given plant has total maintenance hours for the month of 3,753 hours of straight time and 47 hours of overtime. Oil samples drawn by a contract sampling crew consumed 196 hours, and the monthly scheduled vibration readings by operators consumed another 24 hours. The total hours from condition based maintenance work orders totaled 876 hours.

Condition Based Maintenance Hours (%) =
(Condition Based Maintenance Hours / Total Maintenance Labor Hours) × 100

Condition Based Maintenance Hours (%) = [(196 + 876) / (3753 + 47)] × 100
Condition Based Maintenance Hours (%) = (1072 / 3800) × 100
Condition Based Maintenance Hours (%) = 0.282 × 100
Condition Based Maintenance Hours (%) = 28.2%

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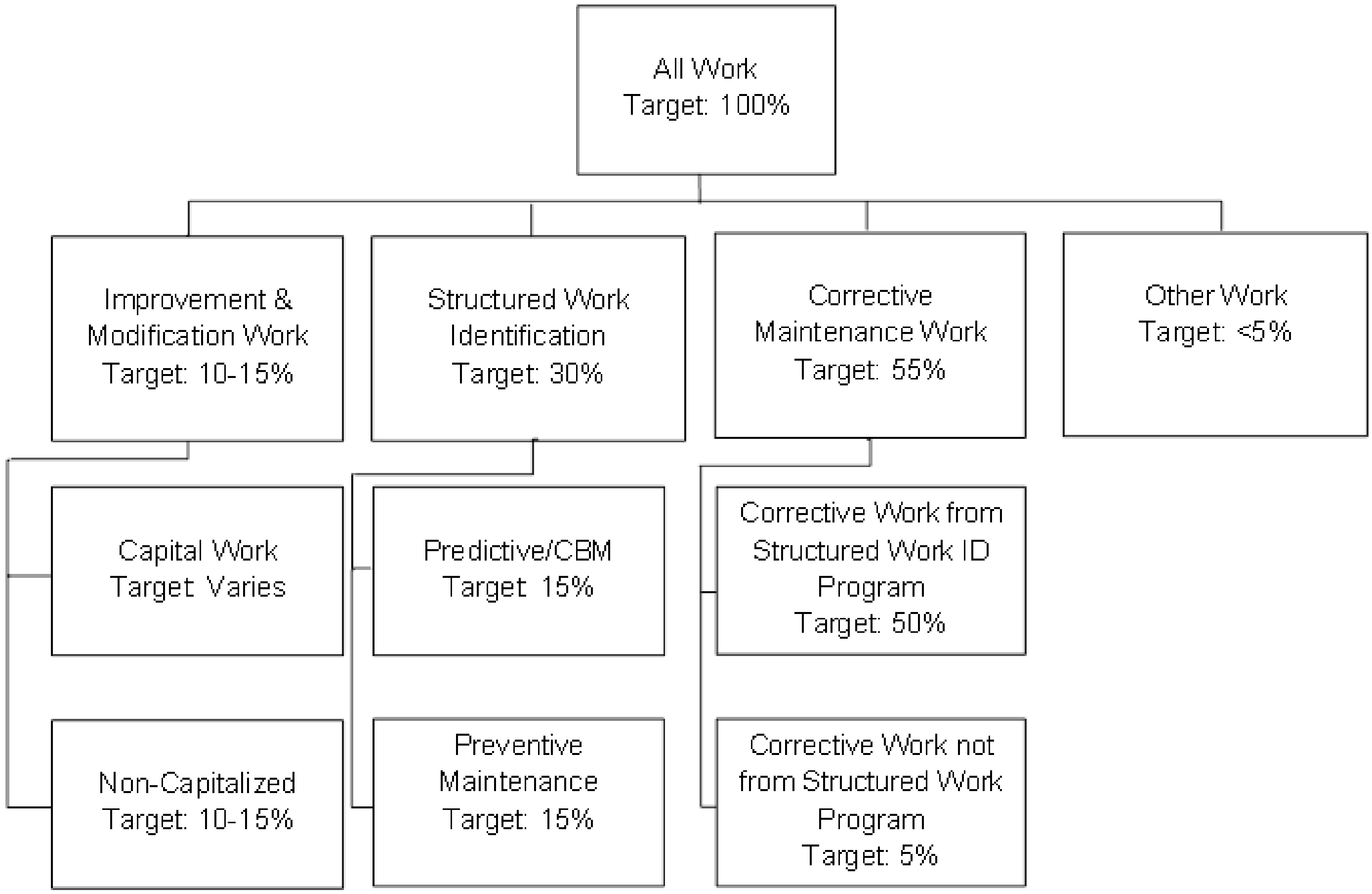

Figure 1. Maintenance Work Type

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee recommends a target of 15% of all maintenance hours. A higher value is achievable and acceptable for newer, technically advanced equipment or processes, with a strategy of lower downtime and less invasive inspection of asset conditions. A lower value is acceptable for older assets where condition base techniques may not be an available alternative. We encourage this metric to be monitored in conjunction with SMRP Metric 5.1.5 for further evaluation of the condition based maintenance program. Condition based maintenance hours are influenced by the age, type, complexity, industry and technology of the assets maintained.

CAUTIONS

The time basis for this metric must be established and applied consistently when comparing or trending this value for analysis. The work order system must be configured in such a way that condition based maintenance work can be differentiated from other work types.

HARMONIZATION

This metric and its supporting definitions are similar or identical to the indicator O19 in standard EN15341.

Note 1: EN 15341 defines conditioned maintenance (hours) as: "Preventive maintenance which includes a combination of condition monitoring and/or inspection and/or testing analysis and the following maintenance actions." SMRP counts the "condition monitoring and/or inspection and/or testing analysis" and does not include the ensuing activities (e.g. corrective maintenance) as CBM.

Conclusion: Calculating the indicator based on the SMRP Metric 5.1.5 definition will give a lower number than by the EN15341 definition since "...the ensuing actions are excluded" from the SMRP definition of CBM.

Note 2: Both EFNMS and SMRP include human senses in CBM.

Note 3: Both EFNMS and SMRP include failure finding tasks for hidden failures in CBM ref. IEC 60300-3-11.

Note 4: EN 15341 and SMRP includes operator CBM hours in the calculation.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the O19 indicator. Details are provided in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

REFERENCES

Mitchell, J. (2002). *Physical Asset Management Handbook* (3rd Ed). Houston, TX. Clarion Technical Publishers.

Schultz, J. and DiStefano, R. (2003). *The Business Case for Reliability*. Presented at the 18th International Maintenance Conference. Fort Myers, FL: NetexpressUSA, Inc.

Taylor, J. (2000 - 2008). *Five Steps to Optimizing Your Preventive Maintenance System.* Retrieved from http://www.reliabilityweb.com.

Wireman Terry Wireman (2004). *Benchmarking Best Practices in Maintenance Management.* New York, NY: Industrial Press, Inc.

WORK MANAGEMENT METRIC

5.1.9 MAINTENANCE SHUTDOWN COST

Published on April 16, 2009
Revised on August 16, 2016

DEFINITION

This metric is the total cost incurred in association with a planned maintenance shutdown expressed as a percentage of the total maintenance cost for the period in which the shutdown(s) occurred.

OBJECTIVE

The objective of this metric is to track the contribution of planned maintenance shutdown cost to total maintenance cost. This value can then be compared to industry benchmarks, be used as a basis for future zero-based budgeting and/or be analyzed for cost reduction opportunities.

FORMULA

Maintenance Shutdown Cost (%) =
[Total Maintenance Shutdown Cost ($) / Total Maintenance Cost ($)] × 100

COMPONENT DEFINITIONS

Maintenance Shutdown Cost
The total cost incurred to prepare and execute all planned maintenance shutdown or outage activities. Includes all staff costs incurred for planning and management of the maintenance activities performed during the shutdown. Includes all costs for temporary facilities and rental equipment directly tied to maintenance activities performed during the shutdown. Does not include costs associated with capital project expansions or improvements that are performed during the shutdown. Calculated and reported for a specific time period (e.g., monthly, quarterly, annually, etc.).

Total Maintenance Cost
The total expenditures for maintenance labor, including maintenance performed by operators such as total productive maintenance (TPM), materials, contractors, services and resources. Includes all maintenance expenses for outages, shutdowns or turnarounds, as well as normal

operating times. Also includes capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include capital expenditures for plant expansions or improvements.

QUALIFICATIONS

1. Time basis: Annually
2. This metric is used by corporate, plant, maintenance and human resources managers to compare to historical trends or to other sites.
3. It provides the best data when used for analyzing trends in maintenance spending, when comparing performance relative to industry benchmarks and when developing a basis for future zero-based budgeting.
4. Sites need to have cost tracking mechanisms in place to capture all expenses associated with the shutdown(s).

SAMPLE CALCULATIONS

A given plant incurs the following costs for their annual maintenance shutdown:

Shutdown planning	$ 15,000
Special equipment rental (cranes, etc.)	$ 22,000
Supplement maintenance contract labor	$125,000
Maintenance labor	$ 36,000
Materials	$192,000
Maintenance shutdown cost	$390,000
Total maintenance cost	$7,200,000

Maintenance Shutdown Cost (%) =
[Maintenance Shutdown Cost ($) / Total Maintenance Cost ($)] × 100
Maintenance Shutdown Cost (%) = ($390,000 / $7,200,000) × 100
Maintenance Shutdown Cost (%) = 0.0542 × 100
Maintenance Shutdown Cost (%) = 5.42%

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee research indicates that best-in-class values for this metric are highly variable by industry vertical and type of facility. SMRP recommends that organizations become involved in trade associations within their industry vertical, as these groups often publish such data about their industry. SMRP also encourages plants to use this metric to help manage your maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric and its supporting definitions are similar to EN 15341 Indicator E20.

Note 1: The difference between this SMRP metric and indicator E20 in EN15341 is that EN 15341 has a broader definition and includes depreciation of maintenance owned equipment and facilities in "total maintenance cost" (e.g., office, workshop and warehouse).

Note 2: The SMRP metric includes the planning and preparation cost for a shutdown. Planning and preparation costs are expected to be less than 5% of the shutdown cost. EN 13541 defines the cost as: "Cost of maintenance performed during shutdowns." This excludes the planning and preparation costs.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the E20 indicator. Additional information is available in the document *Global Maintenance and Reliability Indicators*.

REFERENCES

Marshall Institute (2000). *Establishing meaningful measures of maintenance.* Raleigh, NC.

WORK MANAGEMENT METRIC

5.3.1 PLANNED WORK

Published on June 1, 2009
Revised on August 12, 2015

DEFINITION

This metric is the amount of planned maintenance work that was completed versus the total maintenance labor hours, expressed as a percentage. Planning adds value for the craft worker through preparation and an understanding of work request prior to the commencement of work. Maintenance planning is a highly skilled function that requires a basic knowledge of the maintenance work process, operations, project management, maintenance management system (MMS) and related systems, as well as a practical understanding of the work to be performed. Planning is the "what's required" and "how to" part of any maintenance job.

OBJECTIVES

This metric is designed to measure the amount of planned work that is being executed. Planned work available for execution is identified by the planner. Any completed work done that was not planned is defined as unplanned work. This is a measure of the effectiveness of the routine maintenance planning process. It is a secondary indicator of craft utilization and can provide insight into wrench time improvement potential.

FORMULA

Planned Work (%) =
[Planned Work Executed (hrs) / Total Maintenance Labor Hours (hrs)] × 100

The result is expressed as a percent (%).

PW(%) = (PWE / TML)×100

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COMPONENT DEFINITIONS

Planned Work
Work that has gone through a formal planning process to identify labor, materials, tools, and safety requirements. This information is assembled into a job plan package and communicated to craft workers prior to the start of the work.

Planned Work Executed
Labor hours for work that were formally planned and completed.

Total Maintenance Labor Hours
Expressed in hours and includes all maintenance labor hours for normal operating times as well as outages, shutdowns and turnarounds. If operator hours spent on maintenance activities are captured, they should be included in the numerator and denominator of all applicable metrics. Include labor hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include labor hours used for capital expansions or improvements. Typically, total maintenance labor hours do not include temporary contractor labor hours.

QUALIFICATIONS

1. Time Basis: Weekly
2. This metric is used by operations and maintenance management to understand the opportunity for productivity improvement through planned work.
3. The work plan is independent of work execution.
4. Overtime hours worked during the planning period should be included in the total maintenance labor hours. If these hours are expended on planned work, they should be included in the planned work executed.
5. If operators' hours spent on maintenance activities are captured, they should be included in the numerator and denominator of any applicable metrics.
6. Planned work plus unplanned work (SMRP Metric 5.3.2) must total 100%.

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SAMPLE CALCULATION

In a given week the available maintenance labor hours were:

25 craft workers × 8 hrs/day × 5 days/wk = 1,000 hrs

There were 75 hours of overtime worked on emergency unplanned work. Operators performed 23 hours of unplanned maintenance work and 17 hours of planned preventive maintenance.

Total hours = 1000 + 75 + 23 + 17 = 1115 hours

The total amount of hours expended on planned jobs by maintenance craft workers was 650 hours.

Planned Work =
[(650 hrs + 17 hrs) / (1000 hrs + 75 hrs + 23 hrs + 17 hrs)] × 100 = 59.8%

BEST-IN-CLASS TARGET VALUE

Greater than 90%

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

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WORK MANAGEMENT METRIC

5.3.2 UNPLANNED WORK

Published on June 1, 2009
Revised on August 12, 2015

DEFINITION

This metric is the amount of unplanned maintenance work (hours) that was completed versus the total maintenance labor hours, expressed as a percentage. Planning adds value for the craft worker through preparation and an understanding of work request prior to the commencement of work. Maintenance planning is a highly skilled function that requires a basic knowledge of the maintenance work process, operations, project management, maintenance management system (MMS) and related systems, as well as a practical understanding of the work to be performed. Planning is the "what's required" and "how to" part of any maintenance job. A high percentage of unplanned work is an indication of a reactive work environment and a lack of proper planning.

OBJECTIVES

This metric is designed to measure the amount of unplanned work that is being executed. Planned work available for execution is identified by the planner. Any completed work done that was not planned is defined as unplanned work. This is a measure of the effectiveness of the routine maintenance planning process. It is a secondary indicator of craft utilization and can provide insight into wrench time improvement potential.

FORMULA

Unplanned Work (%) =
[Unplanned Work Executed (hrs) / Total Maintenance Labor Hours (hrs)] × 100

The result is expressed as a percentage (%).

UP(%) =(UWE / TML) × 100

COMPONENT DEFINITIONS

Total Maintenance Labor Hours

Expressed in hours and includes all maintenance labor hours for normal operating times as well as outages, shutdowns and turnarounds. If operator hours spent on maintenance activities are captured, they should be included in the numerator and denominator of all applicable metrics. Include labor hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include labor hours used for capital expansions or improvements. Typically, total maintenance labor hours do not include temporary contractor labor hours.

Unplanned Work

Work that has not gone through a formal planning process.

Unplanned Work Executed

Equal to labor hours for work in which all labor, materials, tools, safety considerations and coordination with the asset owner have not been estimated and communicated prior to the commencement of work.

QUALIFICATIONS

1. Time Basis: Weekly
2. This metric is used by operations and maintenance management to understand the opportunity for productivity improvement through planned work.
3. The work plan is independent of work execution.
4. Overtime hours worked during the planning period should be included in the total maintenance labor hours. If these hours are expended on unplanned work, they should be included in the unplanned work executed.
5. If operators’ hours spent on maintenance activities are captured, they should be included in the numerator and denominator of any applicable metrics.
6. Unplanned work plus planned work (SMRP Metric 5.3.1) must total 100%.

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SAMPLE CALCULATION

In a given week, the available maintenance labor hours were:
25 craft workers × 8 hrs/day × 5 days/wk = 1000 hrs
There were 75 hours of overtime worked on emergency unplanned work. Operators performed 23 hours of unplanned maintenance work and 17 hours of planned preventive maintenance.

Total hours = 1000 + 75 + 23 + 17 = 1,115 hours

The total amount of hours expended on unplanned jobs by maintenance craft workers was 350 hours.

Unplanned Work =
[(350 hrs + 75 hrs + 23 hrs) / (1000 hrs + 75 hrs + 23 hrs + 17 hrs)] × 100 = 40.2%

BEST-IN-CLASS TARGET VALUE

Less than 10%

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

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WORK MANAGEMENT METRIC

5.3.3 ACTUAL COST TO PLANNING ESTIMATE

Published on April 16, 2009

DEFINITION

This metric is the ratio of the actual cost incurred on a work order to the estimated cost for that work order.

OBJECTIVES

This metric measures the accuracy to which work is planned and the efficiency of planned work execution.

FORMULA

Actual Cost to Planning Estimate = [Actual Work Order Cost ($) / Planned Cost ($)] × 100

COMPONENT DEFINITIONS

Actual Work Order Cost
The final cost of the work order after it is closed.

Planned Cost
The planner's estimate of cost to complete the work order. Contingencies should not be included.

QUALIFICATIONS

1. This metric can be measured per work order or per planner.
2. This metric is used by maintenance managers and supervisors to evaluate a planner's estimating accuracy and the stability of the work execution process.
3. This metric can be influenced by many factors. Every aspect of the organization's routine maintenance work process will impact this measure. These include factors such as departmental priorities, politics, how time is charged, etc.

4. Scope changes to the work order should be captured and considered when calculating this metric.
5. The same basis should be used for both the numerator and denominator (e.g., activity, time frame).
6. Only work orders that have been planned, completed and closed should be included.
7. All outstanding purchase orders should clear before the work order is closed. Unpaid purchases can significantly impact the final cost.
8. This metric works best when applied to small sample sizes or individual work orders.
9. See also the related SMRP Metric 5.3.4 and SMRP Metric 5.3.5.
10. If the actual cost is over the estimated cost, the result will be above 100%
11. If the actual cost is under the estimated cost, the result will be below 100%
12. Actual cost to planning estimate is also called estimating accuracy.

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SAMPLE CALCULATION

A maintenance planner plans a carbon steel pipe replacement job by first visiting the job site. He/she identifies the craft skills required, number of craft workers, materials, tools, procedures and permits that are needed for the job. The planner estimates the costs to complete the work order as shown below.

Planned Cost

Replacement pipe	$1,360
Rental, Manlift	$550
Labor (Welder)	$720 (16hrs @ $45/hr)
Labor (Mechanic)	$540 (12hrs @ $45/hr)
Total Estimate	$3,170

After the work order has been completed and closed, the actual costs were as follows:

Actual cost

Replacement pipe	$1,360
Rental, Manlift	$800
Labor (Welder)	$810 (18hrs @ $45/hr)
Labor (Mechanic)	$720 (16hrs @ $45/hr)
Total Labor Material	$3,690

Actual Cost to Planning Estimate = [Actual Work Order Cost ($) / Planned Cost ($)] × 100

Actual Cost to Planning Estimate = [$3,690 / $3,170] x 100
Actual Cost to Planning Estimate = 1.164 x 100 = 116.4%

BEST-IN-CLASS TARGET VALUE

+ 15% (between 85% to 115% of the estimate)

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Hawkins, B. & Kister, T. (2006). *Maintenance planning and scheduling handbook – Streamline your organization for a lean environment.* Burlington, MA: Elsevier Butterworth Heinemann.

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WORK MANAGEMENT METRIC

5.3.4 ACTUAL HOURS TO PLANNING ESTIMATE

Published on June 1, 2009
Revised on August 12, 2015

DEFINITION

This metric is the ratio of the actual number of labor hours reported on a work order to the estimated number of labor hours that were planned for that work order.

OBJECTIVES

This metric measures the accuracy with which work is planned and the efficiency of planned work execution.

FORMULA

Actual Hours to Planning Estimate = (Actual Work Order Hours / Planned Hours) × 100
AHPE = (AWOH / PH) × 100

COMPNENT DEFINITIONS

Actual Work Order Hours
The quantity of hours reported on a work order after it is closed.

Planned Work Order Hours
The planner’s estimate of hours needed to complete the work order.

QUALIFICATIONS

1. Time basis: Per work order or per planner
2. This metric is used by maintenance managers and supervisors to evaluate a planner’s estimating accuracy and the stability of the work execution process.

3. This metric can be influenced by many factors. Every aspect of the organization's routine maintenance work process will impact this measure. These include such factors as departmental priorities, politics, how time is charged, etc.
4. Scope changes to the work order should be captured and considered when calculating this metric.
5. The same basis should be used for both the numerator and denominator (e.g., activity, time frame).
6. Only work that has been planned, completed and closed should be included.
7. This metric works best when applied to small sample sizes or individual work orders.
8. See also the related SMRP Metrics 5.3.3 and SMRP Metric 5.3.5.
9. If the actual hours are over the estimated cost, the result will be above 100%.
10. If the actual hours are under the estimated cost, the result will be below 100%
11. Actual hours to planning estimate is also called estimating accuracy.

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SAMPLE CALCULATION

A maintenance planner plans a carbon steel pipe replacement job by first visiting the job site. He/she identifies the craft skills required, number of craft workers, materials, tools, procedures and permits that are needed for the job. The planner estimates the costs to complete the work order as shown below.

Planned Labor Hours	
Labor (Welder)	16 hrs
Labor (Mechanic)	12 hrs
Total Labor Material	**28 hrs**

After the work order has been completed and closed, the actual labor hours were as follows:

Actual Labor Hours	
Labor (Welder)	18 hrs
Labor (Mechanic)	16 hrs
Total Labor Material	**34 hrs**

Actual Hours to Planning Estimate = (Actual Work Order Hours / Planned Hours) × 100
Actual Hours to Planning Estimate = (34 hrs / 28 hrs) × 100
Actual Hours to Planning Estimate = 1.214 × 100
Actual Hours to Planning Estimate = 121.4%

BEST-IN-CLASS TARGET VALUE

Target should be +/- 10% (between 90% to 110% of the estimate)

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Hawkins, B. & Kister, T (2006). *Maintenance Planning and Scheduling Handbook – Streamline Your Organization for a Lean Environment*. Burlington, MA. Elsevier Butterworth Heinemann.

Hawkins, B. & Smith, R. (2004). *Lean Maintenance–Reduce Costs, Improve Quality, and Increase Market Share*. Burlington, NY: Elsevier Butterworth Heinemann.

Mitchell, J. S. (2007). *Physical Asset Management Handbook* (4th ed). South Norwalk, CT: Industrial Press, Inc.

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WORK MANAGEMENT METRIC

5.3.5 PLANNING VARIANCE INDEX

Published on April 16, 2009

DEFINITION

This metric measures the percentage of planned work orders closed in which the actual cost varied within +/- 20% of the planned cost.

OBJECTIVES

The objective of this metric is to measure the accuracy with which work is planned. This metric may also be a reflection of the efficiency of the execution of planned work.

FORMULA

Planning Variance Index =
(Number of closed planned work orders in which actual costs are within 20% of planned cost / Total number of planned work orders closed) × 100

COMPONENT DEFINITIONS

Actual Work Order Cost
The final cost of the work order after it is closed.

Planned Cost
The planner's estimate of cost to complete the work order. Contingencies should not be included.

Planned Work
Work that has gone through a formal planning process to identify labor, materials, tools, and safety requirements. This information is assembled into a job plan package and communicated to craft workers prior to the start of the work.

Planned Work Executed
Labor hours for work that were formally planned and completed.

QUALIFICATIONS

1. Time basis: Weekly, monthly, quarterly and/or annually.
2. This metric is used by maintenance managers to measure the accuracy of maintenance planners and by maintenance supervisors to assess the efficiency of craft workers.
3. It provides the best data when used to evaluate the effectiveness of the maintenance work planning function.
4. Planning varying index may also be used to assist in the evaluation of the accuracy of a planner.
5. It is assumed that reactive work is not formally planned; therefore, the calculations should not include reactive work orders in either the numerator or the denominator.
6. Blanket or standing work orders are also not included, even if they happen to close during the period being evaluated.
7. The planned job cost will be fixed at the point when planning is completed and the work order is sent for approval. Business rules and governance policy should be in place to prevent modification after that point, unless reapproval of the revised plan is also required.
8. Organizations may elect to choose a different target variance based on the experience and maturity of its planners. The goal would be to approach a 100% accuracy rate, then tighten the target variance.
9. This metric is influenced by many variables, most notably how well the maintenance organization completes work orders and adheres to planning estimates. All aspects of the organization's processes can impact this measure including factors such as departmental priorities, internal politics, how accurately time is charged to work orders, etc.
10. Scope changes to the work orders should be tracked and considered when using this metric.
11. See also the related metrics: SMRP Metric 5.3.3, SMRP Metric 5.3.4 and SMRP Metric 5.3.1.

SAMPLE CALCULATION

In a given month, 4,694 planned work orders were closed. The actual cost varied by more than +/- 20% of the planned cost on 1,254 of these planned work orders.

Planning Variance Index =
(Number of closed planned work orders in which actual costs are within 20% of planned cost / Total number of planned work orders closed) × 100

Planning Variance Index = (3420 / 4694) × 100
Planning Variance Index = 0.729 × 100
Planning Variance Index = 72.9%

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee was unable to find any target ranges, minimum/maximum values, benchmarks or other references for target values for this metric. The committee suggests targeting an improving trend, investigating significant deviations as a means of improving estimating techniques, job planning skills, attention to executing job as planned and craft performance.

SMRP will update this document as appropriate should future work help establish targets for this metric. While no target values are currently available, SMRP encourages plants to use this metric to help manage the maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Wireman, T. (2008). *Maintenance work management process*. New York, N.Y: Industrial Press.

WORK MANAGEMENT METRIC

5.3.6 PLANNER PRODUCTIVITY

Published on April 16, 2009
Revised on August 3, 2016

DEFINITION

This metric measures the average amount of planned work a maintenance planner prepares per month. This metric can be calculated as the number of planned labor hours, number of job plans or the number of planned work orders per month.

OBJECTIVES

The objective of this metric is to quantify the amount of work planned by the maintenance planner.

FORMULA

Planner Productivity (Labor Hours) = Planned Labor Hours / Number of Months

Planner Productivity (Job Plans) = Number of Job Plans / Number of Months

These formulas are listed in rank order of accuracy.

COMPONENT DEFINITIONS

Labor Hours on Job Plans
The planner's estimate of labor hours required to complete a work order at the point when the planning is complete and the work order is sent for approval.

Maintenance Job Plan
Also known as a job plan package, it is the assembly of written and other information that provides guidelines for completing the job safely and efficiently with high quality. Elements to include: labor estimate, material requirements, asset documents, drawings, bills of material, tool list, applicable procedures and safety related items. Should contain enough information to enable the craftsperson to complete the job without having to spend additional time searching

for the information, tools, equipment or material. A minimum job plan includes the work order, labor estimate, material requirements and work order feedback form.

Planned Labor Hours
The planner's estimate of the labor hours required to complete a work order.

Planned Work
Work that has gone through a formal planning process to identify labor, materials, tools, and safety requirements. This information is assembled into a job plan package and communicated to craft workers prior to the start of the work.

Planner
A formally trained maintenance professional who identifies labor, materials, tools and safety requirements for maintenance work orders. The planner assembles this information into a job plan package and communicates it to the maintenance supervisor and/or craft workers prior to the start of the work.

QUALIFICATIONS

1. Time basis: Monthly, quarterly and/or annually
2. This metric is used by maintenance managers to measure and compare maintenance planner productivity.
3. This metric does not take into consideration the quality of the planner's output. This metric is best used in conjunction with other metrics (e.g., SMRP Metric 5.3.4).
4. The ratio of planner to craft (SMRP Metric 5.5.2) is another useful metric when measuring and comparing planner productivity.
5. The number of planned labor hours or job plans must coincide with the number of months being reported.
6. Although this metric is typically measured and reported monthly, it is best used for trending productivity over time.
7. Measuring planned labor hours is typically a more accurate measure of planner productivity than measuring the number of planned jobs since the size of planned jobs can vary significantly.

8. The scope of maintenance job plans varies naturally; consequently, this metric is not normalized when measuring either labor hours or number of job plans.
9. This metric can be used to trend an individual maintenance planner or to compare a number of maintenance planners.
10. It should be recognized that planning maintenance work from scratch will take considerably more time than updating or modifying job plans from a library.
11. Seasoned maintenance planners should produce more job plans or plan more labor hours than a new or inexperienced planner by virtue of their experience and familiarity with personnel and assets.
12. Maintenance job plans can be created from any type of maintenance work order (e.g., corrective, condition based, etc.).
13. When comparing maintenance planners using this metric, the type of work should be similar (e.g., mechanical planner versus mechanical planner and instrument/electrical planner versus instrument/electrical planner).
14. When comparing planner productivity across multiple organizations, caution should be used to ensure that the job plans created by each organization are comparable.
15. The ability of a maintenance planner to plan work is directly related to the systems available to support maintenance planning (e.g., maintenance management system (MMS), bills of material, repair instructions, etc.). The availability of these systems should be a factor when comparing maintenance planner productivity.
16. Maintenance planners are often used as expediters in a reactive maintenance work environment. Expediting is not a maintenance function. Time spent expediting should not be included when measuring planner productivity.
17. Maintenance job plans are also known as a job plan packages.

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SAMPLE CALCULATION

Sample #1 using planned labor hours

In a given year, a maintenance planner prepared job plans with total labor hours as illustrated in the table below.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2,754	3,133	2,908	3,410	2,564	3,309	2,819	2,656	3,098	2,888	2,647	3,215

Planner Productivity (Labor Hours) = Total of Planned Labor Hours / Number of Months
Planner Productivity =
(2,754+3,133+2,908+3,410+2,564+3,309+2,819+2,656+3,098+2,888+2,647+3,215) / 12
Planner Productivity = 35,401 / 12
Planner Productivity = 2,950 labor hours on maintenance job plans per month.

Sample #2 using job plans

In a given year, a maintenance planner prepares job plans as illustrated in the table below.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
104	72	94	90	110	120	86	102	100	92	104	90

Planner Productivity (Job Plans) = Number of Job Plans / Number of Months
Planner Productivity = (104+72+94+90+110+120+86+102+100+92+104+90) / 12
Planner Productivity = 1,164 / 12
Planner Productivity = 97 job plans per month

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee research indicates there is no single value that can be applied based upon the variations in Industry types, skill or experience levels of planners and the deviations in site maturity of maintenance and reliability processes. Calculating this measure, however, will provide valuable insight to the planning process and establish a baseline value for monitoring continuous improvement.

CAUTIONS

The number of job plans created does not take into account the complexity or severity of the work being executed.

Variations in job plan count from period to period are expected due to the varying specifics of each job.

Analysis of planned labor hours and number of job packages together provides improved insight into planner productivity rather than analyzed separately.

Planned labor hours will have some variation with actual hours due in part to planning accuracies. Inaccurate planned hours may increase or decrease the calculated planner productivity metric.

Maturity of a site's maintenance and reliability processes will impact planner productivity.

The calculated value will provide a baseline for any continuous improvement efforts focused on planner productivity.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Brown, Michael V. (2004) *Audel™ Managing Maintenance Planning and Scheduling*, Indianapolis, IN. Wiley Publishing, Inc. Chapter 8, pg. 217-218

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Palmer, R. D. (2006). *Maintenance planning and scheduling handbook*. (2nd ed.). New York City, NY: McGraw-Hill.

WORK MANAGEMENT METRIC

5.4.1 REACTIVE WORK

Published on June 26, 2009
Revised on August 12, 2015

DEFINITION

This metric is maintenance work that interrupts the weekly schedule, calculated as a percentage of the total maintenance labor hours.

OBJECTIVES

This metric is used to measure and monitor the amount of work that is performed outside of the weekly schedule.

FORMULA

Reactive Work (%) =
[Work that breaks into the weekly schedule (hrs) / Total Maintenance Labor Hours] × 100
RW (%) = (WBS / TML) × 100

COMPONENT DEFINITIONS

Total Maintenance Labor Hours
Expressed in hours and includes all maintenance labor hours for normal operating times as well as outages, shutdowns and turnarounds. If operator hours spent on maintenance activities are captured, they should be included in the numerator and denominator of all applicable metrics. Include labor hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include labor hours used for capital expansions or improvements. Typically, total maintenance labor hours do not include temporary contractor labor hours.

Total Reactive Work (Hours)
Maintenance labor hours that were not scheduled and breaks into the weekly schedule. This is usually emergency and unplanned work as a result of unscheduled downtime (SMRP Metric 3.4).

Weekly Schedule
The list of maintenance work to be done in the week. It is usually finalized three to four days before the start of the work week.

QUALIFICATIONS

1. Time Basis: Monthly
2. This metric is used by maintenance and operations management to understand how reactive a plant is (e.g., jumping from one problem to the next).
3. It can be used to show the potential benefit of reducing the level of reactive work and increasing the level of planned and scheduled work.
4. High levels of reactive work can be an indication of poor asset reliability and/or poor work prioritization and management.
5. Examples of reactive work include emergency work and similar work that must be started immediately due the asset condition and/or business requirements (e.g., product demand).
6. Work that is well planned and scheduled is completed more efficiently than reactive work.
7. Ideally, the amount of reactive work is minimal.

SAMPLE CALCULATION

The total hours worked in the month by the maintenance organization on all work types and priorities is 1,000 hours. A total of 350 hours was worked on emergency and similar work that was not on the weekly schedule.

Reactive Work (%) =
[Work that breaks into the weekly schedule (hours) / Total Maintenance Labor Hours] × 100

Reactive Work (%) = [350 hours / 1,000 hours] × 100
Reactive Work (%) = 0.35 × 100
Reactive Work (%) = 35%

BEST-IN-CLASS TARGET VALUE

Less than 10%

CAUTIONS

Best-in-class target value is not achievable without a robust and mature proactive maintenance practice.

HARMONIZATION

This metric and its supporting definitions have the same performance as EN 15341 Indicator O17.

Note 1: The difference between this SMRP metric and indicator O17 in EN 153421 is that metric 5.4.1 measures the labor hours that breaks the maintenance schedule. Indicator O17 measures only the labor hours spent on equipment failure requiring immediate action regardless of schedule or no schedule. When comparing metric 5.4.1 with O17, the metric 5.4.1 will be a higher value since it measures labor hours spent on equipment failure + poor planning + rapid change of priorities.

Depending on the application of the metric, one should be careful about making comparisons.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the O17 indicator. Additional information is provided in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

REFERENCES

Campbell, J. and Reyes-Picknell, J. (2006). *Uptime: Strategies for Excellence in Maintenance Management*. New York, NY: Productivity Press.

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WORK MANAGEMENT METRIC

5.4.2 PROACTIVE WORK

Published on August 2, 2009
Revised on August 12, 2015

DEFINITION

This metric is maintenance work that is completed to avoid failures or to identify defects that could lead to failures. Includes routine preventive and predictive maintenance activities and corrective work tasks identified from them.

OBJECTIVES

This metric is used to measure and monitor the amount of work that is being done in order to prevent failures or to identify defects that could lead to failures.

FORMULA

Proactive Work (%) =
[Work completed on preventive maintenance work orders, predictive maintenance work orders, and corrective work identified from preventive and predictive work orders (hours) / Total Maintenance Labor Hours] × 100

PW (%) = (PWC / TML) × 100

COMPONENT DEFINITIONS

Corrective Work Identified from Preventive and Predictive Maintenance Work Orders
Work identified from preventive maintenance (PM) and predictive maintenance (PdM) work orders is work that was identified through PM and/or PdM tasks and completed prior to failure in order to restore the function of an asset.

Failure
When an asset is unable to perform its required function.

Predictive Maintenance
An equipment maintenance strategy based on assessing the condition of an asset to determine the likelihood of failure and then taking appropriate action to avoid failure. The condition of equipment can be measured using condition monitoring technologies, statistical process control, equipment performance indicators or through the use of human senses.

Preventive Maintenance
Actions performed on a time- or machine-run-based schedule that detect, preclude or mitigate degradation of a component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level.

Total Maintenance Labor Hours
Expressed in hours and includes all maintenance labor hours for normal operating times as well as outages, shutdowns and turnarounds. If operator hours spent on maintenance activities are captured, they should be included in the numerator and denominator of all applicable metrics. Include labor hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include labor hours used for capital expansions or improvements. Typically, total maintenance labor hours do not include temporary contractor labor hours.

QUALIFICATIONS

1. Time Basis: Monthly
2. This metric is used by maintenance and operations management to understand how much time is being spent on activities designed to avoid failures.
3. High levels of proactive work coupled with a low rate of failures can be an indication that operation and maintenance processes are well designed and managed.
4. Ideally, the amount of proactive work would be high to maximize the benefits derived from avoiding failures.

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SAMPLE CALCULATION

The total actual hours worked in the month by the maintenance organization is 1,000 hours. A total of 150 hours was worked on preventive maintenance, 100 hours was worked on predictive maintenance and 400 hours was worked on corrective maintenance from preventive and predictive maintenance work orders.

Proactive Work (%) =
[Work completed on preventive maintenance work orders, predictive maintenance work orders and corrective work identified from preventive and predictive work orders (hrs) / Total Maintenance Labor Hours] × 100

Proactive Work (%) =
[(150 hours + 100 hours + 400 hours) / 1,000 hours] × 100
Proactive Work (%) = [650 hours / 1,000 hours] × 100
Proactive Work (%) = 0.65 × 100
Proactive Work (%) = 65%

BEST-IN-CLASS TARGET VALUE

Greater than 80%

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric and its supporting definitions have the same performance as EN 15341 Indicator O18.

Note 1: Proactive maintenance contains the EN 13306 definition of preventive maintenance + the part of corrective maintenance tasks originating from findings during predictive and preventive activities.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the O18 indicator. Additional information is provided in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

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WORK MANAGEMENT METRIC

5.4.3 SCHEDULE COMPLIANCE - HOURS

Published on May 14, 2009
Revised on August 12, 2015

DEFINITION

This metric is a measure of adherence to the maintenance schedule, expressed as a percent of total time available to schedule.

OBJECTIVES

This metric measures compliance to the maintenance schedule and reflects the effectiveness of the work scheduling process.

FORUMLA

Schedule Compliance (%) =
[Scheduled Work Performed (hours) / Total Time Available to Schedule (hours)] × 100

SC (%) = (SWP / TAS) × 100

COMPONENT DEFINITIONS

Scheduled Work Performed (Hours)
The actual hours worked on scheduled work per the maintenance schedule.

Total Time Available to Schedule
The total number of craft hours available to schedule. It does not include vacation, illness or injury and other similar time off.

QUALIFICATIONS

1. Time Basis: Daily or Weekly.
2. This metric is used by maintenance management to identify opportunities for efficiency improvement.

3. Scheduling is the "when" and involves assigning all required resources to perform the work at the optimum time to facilitate the most efficient execution of the work.
4. The scheduler reviews the planned work package which includes a written scope, work plan, manpower requirements (by craft workers), all required permits, special tools, equipment (such as mobile work platforms, cranes, lifts, etc.) and parts availability. This information is compared to the production schedule and the manpower available to determine the optimum time to schedule the work.
5. Any work performed that is not on the schedule is unscheduled work.
   This metric is a secondary indicator of planning effectiveness, reactive work and craft worker effectiveness.
6. See also related SMRP Metric 5.4.4 which measures weekly schedule performance using work orders.

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SAMPLE CALCULATION

Daily Basis:
For a given workday the available work hours are
20 craft workers × 8 hrs/day = 160 hrs/day

On this day, 140 hrs of work was scheduled, while 20 hrs were not scheduled due to anticipated emergency work or other unscheduled work.

The actual scheduled worked performed was limited to 100 hours due to emergency work and work that extended beyond the scheduled time.

Schedule Compliance (%) =
[Scheduled Work Performed (hours) / Total Time Available to Schedule (hours)] × 100

Schedule Compliance (%) = [100 hours / 160 hours] × 100
Schedule Compliance (%) = 0.625 × 100
Schedule Compliance (%) = 62.5%

Weekly Basis:
For a given week, the available work hours are
20 craft workers × 8 hrs/day × 5 days/week = 800 hours.
During this week, 675 hours of work was scheduled, while 125 were not scheduled due to anticipated emergency work or other unscheduled work.

The actual scheduled worked performed was limited to 482 hrs due to emergency work and work that extended beyond the scheduled time.

Schedule Compliance (%) =
[Scheduled Work Performed (hours) / Total Time Available to Schedule (hours)] × 100

Schedule Compliance (%) = [482 hours / 800 hours] × 100
Schedule Compliance (%) = 0.603 × 100
Schedule Compliance (%) = 60.3%

BEST-IN-CLASS TARGET VALUE

Greater than (>) 90%

CAUTIONS

For this metric to be accurate, all (100%) maintenance hours available must be scheduled.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

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WORK MANAGEMENT METRIC

5.4.4 SCHEDULE COMPLIANCE – WORK ORDERS

Published on April 16, 2009

DEFINITION

This metric is a measure of adherence to the weekly maintenance work schedule, expressed as a percent of total number of scheduled work orders.

OBJECTIVES

This metric measures compliance to the weekly maintenance schedule and reflects the effectiveness of the work scheduling process.

FORMULA

Scheduled Compliance (%) =
(Number of work orders performed as scheduled / Total number of scheduled work orders) × 100

COMPONENT DEFINITIONS

Number of Work Orders Performed as Scheduled
The number of work orders on the maintenance schedule that were executed when scheduled are considered performed as scheduled.

Total Number of Scheduled Work Orders
The total number of work orders on the weekly schedule.

Weekly Schedule
The list of maintenance work to be done in the week. It is usually finalized three to four days before the start of the work week.

QUALIFICATIONS

1. This metric is calculated on a weekly basis.
2. This metric is used by maintenance management to identify opportunities for efficiency improvement.
3. Rescheduled work that reappears on a weekly maintenance schedule cannot be completed as scheduled since the original schedule date has already passed. Count only work orders that were actually completed as scheduled on the original schedule.
4. See also related SMRP Metric 5.4.3 which measures schedule performance in hours.
5. Any work performed that is not on the schedule is unscheduled work.
6. This metric is a secondary indicator of planning effectiveness, reactive work and craft worker effectiveness.

SAMPLE CALCULATION

For a given week there were 135 work orders scheduled. At the end of the week 113 scheduled work orders and 45 emergency work orders were completed.

Scheduled Compliance (%) = (Number of work orders performed as scheduled / Total number of scheduled work orders) × 100

Scheduled Compliance (%) = (113 / 135) × 100
Scheduled Compliance (%) = 0.837 × 100
Scheduled Compliance (%) = 83.7%

Note: The emergency work orders do not count as they broke into the weekly schedule.

BEST-IN-CLASS TARGET VALUE

Greater than (>) 90%

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric and its supporting definitions are similar or identical to the indicator O22 in standard EN 15341.

Note 1: Both metrics/indicators measure schedule compliance and not planned and scheduled performance.

Note 2: Metric 5.4.4 is calculated on a weekly basis. EN O22 is calculated on any given time frame - also weekly.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the O22 indicator.

Additional information is available in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP library.

REFERENCES

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WORK MANAGEMENT METRIC

5.4.5 STANDING WORK ORDERS

Published on April 16, 2009

DEFINITION

This metric is the ratio of the hours worked on standing work orders to the total maintenance labor hours, expressed as a percentage.

OBJECTIVES

This metric measures the amount of maintenance work charged to standing work orders.

FORMULA

Standing Work Orders (%) =
[Hours worked on standing work orders / Total maintenance labor hours] × 100

COMPONENT DEFINITIONS

Standing Work Order
A work order opened for a specific period of time to capture labor and material costs for recurring or short duration maintenance work and for work that is not associated with a specific piece of equipment where tracking work history or formalizing individual work orders is not cost effective or practical. Examples include: shop housekeeping, meetings, training, etc. Standing work orders are also referred to as a blanket work orders.

In some cases involving specific equipment, a standing work order may be used if the time and cost associated with the work is insignificant and if there is no need to capture maintenance history (e.g., time required to perform a routine daily adjustment).

Total Maintenance Labor Hours
Expressed in hours and includes all maintenance labor hours for normal operating times as well as outages, shutdowns and turnarounds. If operator hours spent on maintenance activities are captured, they should be included in the numerator and denominator of all applicable metrics. Include labor hours for capital expenditures directly related to end-of-life machinery

replacement so that excessive replacement versus proper maintenance is not masked. Does not include labor hours used for capital expansions or improvements. Typically, total maintenance labor hours do not include temporary contractor labor hours.

QUALIFICATIONS

1. This metric is calculated on a weekly, monthly or annual basis.
2. This metric is used by maintenance and operations managers to understand the amount of maintenance work not captured against a specific piece of equipment.
3. Standing work orders should be used on a limited basis, recognizing that work history is not captured and the data that is captured does not lend itself to analysis.
4. Standing work orders do not provide any detail or work history and are used primarily to capture maintenance costs.
5. Standing work orders should not be a substitute for emergency work orders since important work history will not be captured for the emergency condition.
6. Excessive use of standing work orders may be an indication that a work order system is not being used effectively.
7. Work types should not be mixed within a standing work order.
8. Standing work orders should be closed periodically, typically monthly but no greater than annually, and a new standing work order should be created at the start of the next period to avoid abuse and raise awareness of associated costs.
9. Standing work orders are typically not scheduled on a weekly schedule.

SAMPLE CALCULATION

For a given month 100 hours were spent on standing work orders. The total maintenance hours worked during the month was 1,500 hours.

Standing Work Orders (%) =
[Hours worked on standing work orders / total maintenance labor hours] × 100

Standing Work Orders (%) = [100 / 1,500] × 100
Standing Work Orders (%) = 0.067 × 100
Standing Work Orders = 6.7%

BEST-IN-CLASS TARGET VALUE

Less than <10%

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

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WORK MANAGEMENT METRIC

5.4.6 WORK ORDER AGING

Published on April 16, 2009

DEFINITION

This metric measures the age of active work orders by using the work order creation date and comparing it to today's date to calculate the work order age, expressed in number of days.

OBJECTIVES

The objective of this metric is to track work order aging to ensure effective work order backlog management and to verify the appropriate usage of the work order priority system. Work orders are segregated into age range categories based on their individual age, and criteria are established for each age range. Deviations from the criteria indicate the need to review and update the backlog or to identify and correct the causes of work orders that are not being completed in a timely manner, based on priority and age.

FORMULA

Work Order Age (days) = Today's Date – Work Order Creation Date

Work orders are segregated into different age range categories and displayed as number of work orders and percent of total work orders for each age category.

COMPONENT DEFINITIONS

Today's Date
The current work day.

Work Order Creation Date
The date the work order was written and entered into the maintenance management system. This could also be called a work request or notification date, depending on the maintenance management system in use.

QUALIFICATIONS

1. Time basis: Monthly
2. This metric is used by maintenance and operations personnel to ensure work is being completed in a timely manner.
3. It is used as a screening metric to assess work order flow through the backlog and/or problems with work order priority setting. Deviations from the established criteria suggests the need to review and update the backlog or to identify and correct the causes of work orders that are not being completed in a timely manner, based on priority and age.
4. Each plant or company will need to determine how best to categorize and analyze the age of their work orders, such as categorize by equipment criticality, work order priority, work order type, etc.
5. Age ranges should be established and standardized plant and companywide.
6. The resultant data can be presented in various formats (e.g., dashboard, pie chart, spreadsheet, etc.).
7. Work orders are grouped by age into different age categories (e.g., 0- 30 days, 31-90 days, 91-180 days, 181-365 days, >365 days).
8. Deviations from the priority completion criteria suggests the need to review and update the backlog or to identify and correct the causes of work orders that are not being completed in a timely manner, based on priority and age.

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SAMPLE CALCULATION

A given plant has 137 active work orders in the system with ages as follows:

Category	Number of Work Orders
0–30 days	38
31–90 days	69
91–180 days	20
181–365 days	8
>365 days	2

The company has established target ranges for the number of work orders within each age category (low and high targets). A dashboard was created to provide a visual indication of the work order age data relative to the targets. Utilizing green for acceptable and red for unacceptable, the work order aging dashboard is shown below. Note: The low and high targets in the sample calculation are for illustrative purposes only and do not necessarily imply best practice values.

Age Category	#WOs	%WOs	Low Target %	High Target %
0-30 days	38	28%	20%	30%
31-30 days	69	50%	40%	60%
91-180 days	20	15%	10%	30%
181-365	8	6%	0%	5%
>365 days	2	1%	0%	0%
(green)	within target			
(red)	outside target			

The percentage of active work orders greater than 181 days old is outside the established target. Further analysis is required to determine the root cause.

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee was unable to find any target ranges, minimum/maximum values, benchmarks or other references to target values for this metric. SMRP will update this document as appropriate should future work help establish targets for this metric. While no target values are currently available, SMRP encourages plants to use this metric to help manage the maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Approved by consensus of the SMRP Best Practice Committee.

WORK MANAGEMENT METRIC

5.4.7 WORK ORDER CYCLE TIME

Published on April 16, 2009

DEFINITION

This metric is the time from the creation of a work order until it is closed in the maintenance management system (MMS).

OBJECTIVES

The objective of this metric is to understand and measure how long it takes to complete work, from creation to completion.

FORMULA

Work Order Cycle Time = Work Order Completion Date – Work Order Creation Date (in Days)

COMPONENT DEFINITIONS

Work Order Creation Date

The date the work order was written and entered into the maintenance management system. This could also be called a work request or notification date, depending on the maintenance management system in use.

Work Order Completion Date

The date the work order was closed in the maintenance management system. This is considered the technical completion date and includes that all data is captured within the MMS, including work done, hours worked, parts used, etc.

QUALIFICATIONS

1. Time basis: Trended monthly, quarterly and for annual comparisons.
2. This metric is used by maintenance managers and reliability engineers.

3. The measure includes time in the following stages: backlog, planning, sourcing material, waiting to be scheduled and execution.
4. The measure can be expressed in different ways and are illustrated in the calculation below.
    a. As a percent of work orders completed in different time ranges in a period
    b. The average time for work orders completed during a period of time
    c. The number of work orders completed in different age ranges.
5. When the measure is expressed as a percentage of work orders in different time ranges, it can be used to identify low priority work that is being done quickly (e.g., in less than a week) without planning in a reactive manner.
6. The cycle time will vary by work order priority; it would be expected the higher the priority, the shorter the cycle time.
7. The cycle time will vary by the type of work. Shutdown or turnaround cannot be completed until the shutdown or turnaround; therefore, it could be years until they are completed.
8. This metric is primarily used internally within a maintenance group to understand and diagnose issues with their maintenance work process. Due to differences in the required reaction time to different equipment and industries, it is difficult to use as a benchmarking measure.
9. Use with SMRP Metric 5.4.6.

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SAMPLE CALCULATION

For a group of work orders completed during a certain period, the creation and completion dates are as follows:

Work Order	Completion Date	Creation Date	Difference in days
50123	Dec. 5	July 5	153
50134	Dec. 5	Aug. 10	117
50145	Dec.7	Sept. 4	94
50166	Dec. 8	Oct. 8	64
50177	Dec 8	Nov 26	13
50175	Dec 5	Nov 26	9
50186	Dec. 9	Dec. 5	4
		Average	64.9

Work Order Cycle Time = Work Order Completion Date – Work Order Creation Date (in Days)

Method A

Percent less than 7 days 1/7 = 14.3%
Percent 8–14 days 2/7 = 28.6%
Percent more than 14 days 5/7 = 71.4%

Method B

For all the work orders completed over the period, the average work order cycle time is 64.9 days.

Method C

Number under 30 days 3
Number 31-90 days 1
Number over 90 days 3

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee was unable to find any target ranges, minimum/maximum values, benchmarks or other references to target values for this metric. SMRP will update this document as appropriate should future work help establish targets for this metric. While no current target values are available, SMRP encourages plants to use this metric to help manage the maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Approved by consensus of SMRP Best Practice Committee.

WORK MANAGEMENT METRIC

5.4.8 PLANNED BACKLOG

Published on April 16, 2009
Revised on August 24, 2016

DEFINITION

This metric is the combination of the quantity of work that has been fully planned for execution, but is not ready to be scheduled and work that is ready to be performed. Also known as ready work.

OBJECTIVES

The objective of this metric is to measure the quantity of work yet to be performed in order to ensure that labor resources are balanced with the available work and to identify potential gaps in resource availability. It can also be used to identify planning resource issues.

FORMULA

Planned Backlog (weeks) = (Planned Work + Ready Work) / Crew Capacity

COMPONENT DEFINITIONS

Crew Capacity
The portion of the weekly maintenance labor complement that is available to work on backlog jobs. It is the sum of the straight time hours per week for each individual in the crew, plus scheduled overtime, less indirect commitments (e.g., training, meetings, vacations, etc.).

Planned Work
Work that has gone through a formal planning process to identify labor, materials, tools, and safety requirements. This information is assembled into a job plan package and communicated to craft workers prior to the start of the work.

Ready Work
Work that has been prepared for execution (e.g., necessary planning has been done, materials procured and labor requirements have been estimated).

QUALIFICATIONS

1. Time Basis: Weekly, monthly or as required by facility needs.
2. All components need to be measured in the same units, usually man-hours.
3. This metric is used by maintenance management, supervision, planners and schedulers to balance labor resources against available work.
4. If insufficient resources are available, workers can work overtime or contractors can be used to supplement the workforce in order to keep the labor capacity balanced with the workload.
5. Planned backlog can vary depending on the needs of the facility and the status of major overhauls, turnarounds or large maintenance projects.
6. Planned backlog work may not be ready to schedule for various reasons, such as timing associated with equipment availability, environmental issues or concerns, turnaround planning, availability of materials, availability of special tools or equipment (e.g., crane), awaiting equipment access from production, etc.

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SAMPLE CALCULATION

A given 10-person work crew works a standard 40-hour week with 6% overtime authorized each week. There are 200 hours of planned backlog which is not yet ready to be scheduled and 845 hours of ready work. Two workers are scheduled to be on vacation during the week and one is reassigned to the engineering department. Each worker is also required to spend 2 hours per week in computer-based training. Safety meetings are held on Wednesday mornings and last 30 minutes.

Crew Capacity:
Straight time hours available = 10 people × 40 hours/week = 400 hours/week
Approved overtime (6% of straight time) = 0.06 × 400 hours/week = 24 hours/week

Crew Capacity (gross):
400 hours (straight time) + 24 hours (overtime) = 424 hours/week

Capacity Impacts:
Vacation = (2 workers × 40 hours) + (0.06 × 2 worker × 40 hours) = 84.8 hours
Reassigned = (1 Worker × 40 hours) + (0.06 × 1 worker × 40 hours) = 42.4 hours
Scheduled training = 7 workers × 2 hours = 14 hours
Safety meeting = 7 workers × 0.5 hour = 3.5 hours
Weekly average consumption for emergency work = 46 hours

Total Capacity Impacts:
84.8 hours+ 42.4 hours + 14 hours + 3.5 hours + 46 hours = 190.7 hours
Crew Capacity (net) = 424 hours/week – 190.7 hours/week = 233.3 hours/week
Planned Backlog (weeks) = (Planned Work + Ready Work) / Crew Capacity
Planned Backlog (weeks) = (200 hours + 845 hours) / 233.3 hours/week
Planned Backlog (weeks) = 1045 hours / 233.3 hours/week
Planned Backlog = 4.48 weeks

BEST-IN-CLASS TARGET VALUE

Ready available backlog is equal to two to four weeks of labor hours. Total backlog (available and unavailable) is equal to four to six weeks of labor hours.

CAUTIONS

See qualifications outlined in this document.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

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WORK MANAGEMENT METRIC

5.4.9 READY BACKLOG

Published on June 14, 2009
Revised on August 12, 2015

DEFINITION

This metric is the quantity of work that has been fully prepared for execution, but has not yet been executed. It is work for which all planning has been done and materials procured, but is waiting to be scheduled for execution.

OBJECTIVES

This metric measures the quantity of work yet to be performed to ensure labor resources are balanced with the available work.

FORMULA

Ready Backlog = Ready Work / Crew Capacity

COMPONENT DEFINITIONS

Crew Capacity

The portion of the weekly maintenance labor complement that is available to work on backlog jobs. It is the sum of the straight time hours per week for each individual in the crew, plus scheduled overtime, less indirect commitments (e.g., training, meetings, vacations, etc.).

Ready Work

Work that has been prepared for execution (e.g., necessary planning has been done, materials procured and labor requirements have been estimated).

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QUALIFICATIONS

1. Time Basis: Weekly
2. This metric is used by maintenance management to balance labor resources against available work. If insufficient resources are available, workers can work overtime or contractors can be used to supplement the workforce in order to keep labor capacity balanced with workload.
3. If ready backlog is less than two weeks, it may be difficult to create a weekly schedule for the full work crew.
4. If ready backlog is greater than four weeks, there is likelihood that work will not be completed in a timely fashion (e.g., excessive work order aging).
5. Two to four weeks of ready backlog facilitates level scheduling of the work crew.

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SAMPLE CALCULATION

A given 10-person work crew works a standard 40-hour week with 6% overtime authorized each week. There are 845 hours of ready backlog. Two workers are scheduled to be on vacation during the week and 1 crew member is reassigned to the engineering department. Each worker is also required to spend 2 hours per week in computer-based training. Safety toolbox meetings are held on Wednesday mornings for 30 minutes.

The weekly capacity for this crew is as follows:
Straight time hours available = 10 people × 40 hours/week = 400 hours/week
Scheduled overtime (6% of straight time) = 0.06 × 400 hours/week = 24 hours/week
Gross weekly capacity = 400-hours straight time + 24-hours overtime = 424 hours/week

Indirect commitments are as follows:
Vacation = (2 workers × 40 hours) + (0.06 × 2 workers × 40 hours) = 84.8 hours
Reassigned = (1 worker × 40 hours) + (0.06 × 1 worker × 40 hours) = 42.4 hours
Scheduled training = 7 workers × 2 hours = 14 hours
Safety meeting = 7 workers × 0.5 hour = 3.5 hours
Total indirect commitments = 84.8 hours + 42.4 hours + 14 hours + 3.5 hours = 144.7 hours

Direct commitments are as follows:
Weekly average consumption for emergency work = 46 hours
Net Crew Capacity for the week =
Gross Crew Capacity – (Indirect Commitments + Direct Commitments)
Net Crew Capacity for the week = 424 hours – (144.7 hours + 46 hours)
Net Crew Capacity for the week = 424 hours – 190.7 hours = 233.3 hours
Ready Backlog = 845 hours / 233.3 hours = 3.62 weeks

BEST-IN-CLASS TARGET VALUE

Two to four weeks

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

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WORK MANAGEMENT METRIC

5.4.10 PREVENTIVE MAINTENANCE (PM) & PREDICTIVE MAINTENACNE (PDM) WORK ORDER COMPLIANCE

Published on April 16, 2009

DEFINITION

This metric measures the percentage of preventive maintenance (PM) and predictive maintenance (PdM) work orders that were completed past the expected date (e.g., overdue) for a given completion date range. The overdue variance is calculated for each work order. It is recommended that results are grouped in ranges of overdue variance (%) and by criticality rank.

OBJECTIVES

The objective of this metric is to capture and trend PM and PdM work order completion information and insure the assets are being managed according to their criticality.

FORMULA

Count of PM & PdM work orders completed within the report date range, grouped by criticality rank

PM & PdM work order overdue variance = ([actual interval / planned frequency] × 100) -100

Overdue variance range – selected based on the points at which the level of management response changes.

% of PMs within variance range by criticality rank– [count of PMs with overdue variance in a given range / total PMs] x 100

COMPONENT DEFINITIONS

Actual Preventive Maintenance (PM) & Predictive Maintenance (PdM) Interval
The actual interval or cycle for the repeated completion of a given preventive (PM) or predictive maintenance (PdM) task work order, measured in hours, days or months.

Critical Systems
The systems that are vital to continued operations, will significantly impact production or have inherent risks to personnel safety or the environment should they fail.

Criticality Analysis
A quantitative analysis of events and faults and the ranking of these in order based on a weighted combination of the seriousness of their consequences and frequency of occurrence.

Planned Preventive Maintenance (PM) & Predictive Maintenance (PdM) Frequency
Planned frequency or cycle over which a given preventive maintenance (PM) or predictive maintenance (PdM) task is to be repeated, measured in hours, day or months.

Preventive Maintenance (PM) & Predictive Maintenance (PdM) Frequency
Cyclical period of a specific unit of measure in which preventive maintenance (PM) and predictive maintenance (PdM) activities are repeated.

Report Date Range
The selected calendar period in which work order completion occurs.

Systems
A set of interrelated or interacting elements. In the context of dependability, a system will have the following: (a) a defined purpose expressed in terms of required functions; (b) stated conditions of operation and (c) defined boundaries.

QUALIFICATIONS

1. Either time or meter basis
2. This metric is used by maintenance, reliability and operations personnel.
3. It provides the best data when used to understand how effective maintenance management is at completing PM and PdM work tasks as expected.
4. All PM & PdM work orders should be ordered according variance and criticality rank.

SAMPLE CALCULATION

Equipment PM has competed at 40 Days versus a frequency of 30 Days planned. This reflects in a 33% variance in PM compliance.

([Actual Interval / Planned Frequency] × 100) -100

([40 Days / 30 Days] × 100) -100 = 33% Variance

Sample calculation is one data point in the table below.

Mar-10		**Variance**					
Criticality Rank High to Low	PM Count	<-15%	+/- 15%	>+15 % and <+25 %	>+25 % and <+50 %	>+50 %	Not Performed
5	68	4%	69%	21%	6%	0%	0%
4	53	2%	68%	17%	11%	2%	0%
3	110	0%	65%	19%	11%	4%	1%
2	39	0%	72%	10%	15%	3%	0%
1	32	0%	44%	38%	9%	9%	0%

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

None

WORK MANAGEMENT METRIC

5.4.11 PREVENTIVE MAINTENANCE (PM) & PREDICTIVE MAINTENANCE (PDM) WORK ORDERS OVERDUE

Published on February 23, 2010
Revised on August 24, 2016

DEFINITION

This metric measures all active preventive maintenance (PM) and predictive maintenance (PdM) work orders (e.g., ongoing, not closed) in the system not completed by due date.

OBJECTIVES

The objective is to review PM and PdM work order backlog, and develop plans to resolve the overdue tasks within reasonable timeframes.

FORMULA

Segregate the overdue work orders into categories based on the length of time that the work order is overdue. For example, the following criteria can be used to define overdue:

Category	Criterion
1	Due date is >0 and <=30 days overdue
2	Due date is >30 and <= 90 days overdue
3	Due date is >90 days overdue

Or if PM & PdM is executed by hours, the following categories applies:

Category	Criterion
1	Hours Past scheduled Time is >0 and <=25%
2	Hours Past scheduled Time is >25% and <= 50%
3	Hours Past scheduled Time is > 50%

Record the work order counts for each category based on established criteria and display in a table by asset or task criticality rank (e.g., criticality analysis) and overdue category.

The calculation of work orders overdue based on days is:
Days overdue = (Current date – Due date)

The calculation of work orders overdue based on hours is:
Hours past Scheduled Time =
([Current Interval Hours - Planned Interval Hours] / Planned interval Hours) x 100
Include additional formulae if metric can be calculated more than one way.

COMPONENT DEFINITIONS

Active Work Order
Any work order that is not closed in the maintenance management system (MMS).

Criticality Analysis
A quantitative analysis of events and faults and the ranking of these in order based on a weighted combination of the seriousness of their consequences and frequency of occurrence.

Current Date
The current calendar date that the report is run.

Current Interval Hours
The number of actual hours on a piece of equipment since the last preventive maintenance (PM) or predictive maintenance (PdM) was performed.

Days
Calendar days versus operating days/time.

Due date
The required completion date of the preventive maintenance (PM) or predictive maintenance (PdM), including the grace period.

Planned Interval Hours
The number of planned operating hours on a piece of equipment between scheduled preventive maintenance (PM) or predictive maintenance (PdM) events.

QUALIFICATIONS

1. Time Basis: Monthly
2. This metric is used by plant maintenance personnel to better understand, and focus on overdue PM and PdM work orders.
3. The number of overdue PMs can change by the minute and the metric should be trended to identify systemic problems.
4. The categories and/or criteria used to determine overdue in the metric definition are for example only. Plants will have to determine their own categories and criteria for defining overdue.
5. Even though the metric is the total of all overdue work orders and a snapshot for the time period analyzed, a Pareto analysis or similar criticality analysis such as ranking by criticality or risk should be used to identify the most important categories to address first.
6. A review process should be in place for all PM/PdM >30 days or >25% by hours.

SAMPLE CALCULATION

PM and PdM Work Order Backlog Status

The MMS produced the following number of work orders that were overdue at the time the report was run.

Criticality Analysis	Category 1	Category 2	Category 3
5	1	1	4
4	3	2	8
3	5	2	10
2	4	1	14
1	6	4	12
Total	19	10	48

Total Overdue work orders = 19+10+48 = 77

BEST-IN-CLASS TARGET VALUE

Less than (<) 5%. This indicator checks the timeliness of the work order completion. When a work order is initiated, the goal is to finish the work in two to four weeks. This level keeps the backlog current and prevents perceived lack of responsiveness on the part of the maintenance organization. The goal is zero work orders overdue. Although this is difficult to achieve, the lower the percentage, the better the performance of the maintenance organization.

This indicator is derived by dividing the number of work orders overdue (exceeding the two to four week backlog) by the total number of work orders. The percentage highlights the amount of work not being performed in a timely fashion. The manager should then have the ability to examine the individual work orders to see what can be done to expedite completion.

Strengths: This indicator is valuable for insuring timely service of the maintenance department.

Weaknesses: There is no major weakness to this indicator. It is recommended to all organizations trying to improve their responsiveness.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Hawkins, B. & Smith, R. (2004). *Lean maintenance–reduce costs improve quality, and increase market share*. Burlington, NY: Elsevier Butterworth Heinemann. New York City, NY: McGraw-Hill.

Smith, R. and Mobley, K (2008). Rules of thumb for maintenance and reliability engineers. Burlington, NY: Elsevier Butterworth Heinemann.

Wireman, Terry. (2005). Developing Performance Indicators for Managing Maintenance, 2nd Ed., New York, NY: Industrial Press; Chapter 5.17 pg. 107-108

WORK MANAGEMENT METRIC

5.4.12 PREVENTIVE MAINTENANCE (PM) & PREDICTIVE MAINTENANCE (PdM) YIELD

Published on April 16, 2009

DEFINITION

This metric measures the volume of corrective work that results directly from preventive maintenance (PM) and predictive maintenance (PdM) work orders. The amount of repair and replacement work that is identified when performing PM or PdM work compared to the amount of PM or PdM work being done.

OBJECTIVES

The objective of this metric is to measure the corrective work generated by the PM and PdM programs as a measure of the effectiveness of the PM and PdM programs in identifying potential failures.

FORMULA

PM and PdM Yield =
Corrective Work Identified from Preventive and Predictive Maintenance Work Orders (hours) / PM and PdM (hours)

COMPONENT DEFINITIONS

Corrective Work Identified from Preventive and Predictive Maintenance Work Orders
Work identified from preventive maintenance (PM) and predictive maintenance (PdM) work orders is work that was identified through PM and/or PdM tasks and completed prior to failure in order to restore the function of an asset.

Preventive Maintenance (PM)
Actions performed on a time- or machine-run-based schedule that detect, preclude or mitigate degradation of a component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level.

Predictive Maintenance (PdM)
An equipment maintenance strategy based on assessing the condition of an asset to determine the likelihood of failure and then taking appropriate action to avoid failure. The condition of equipment can be measured using condition monitoring technologies, statistical process control, equipment performance indicators or through the use of human senses.

QUALIFICATIONS

1. Time basis: Monthly
2. This metric is used by plant maintenance and reliability personnel
3. It provides the best data when used to understand the effectiveness of PM and PdM tasks.
4. It should not be applied to a single PM and PdM instance on a single asset.
5. This metric should be calculated as an average for a large maintenance department.
6. The best indicator of the yield of PM and PdM work is the reliability of equipment; however, this is a lagging indicator. Measuring work generated from the PM and PdM work can be a leading indicator of the effectiveness of the program, but should be used with caution. This is a measure of how well potential failures are being identified before they occur.
7. The measure assumes that since a PM or PdM is in place, there is a desire to avoid the failure.
8. The target value for the measure would be a mid-range value. Very low or very high numbers would be cause for investigation.
9. This metric should be considered in the context of overall equipment reliability.
10. The volume of PM and PdM work being performed should be considered. In the examples below, the PM and PdM work is assumed to be at a reasonable level.
    (a) Low reliability and very little work identified from the PM and PdMs
        - Review the PM and PdM work, possible reliability centered maintenance (RCM) candidate

    (b) Low reliability and 0.8 hours per hour being generated from the PM and PdMs
        - Review the PM & PdM work, possible RCM candidate and possibly some redesign opportunities

(c) Low reliability and many hours per hour being generated from the PM and PdMs

- Check for infant mortality, review maintenance practices and possible redesign opportunities

(d) High reliability and very little work identified from the PM and PdMs

- PM review for optimization is possible.

Caution: Care must be taken in the optimization process to ensure that PMs and PdMs to identify or prevent high consequence failures are not eliminated or the frequency reduced, putting the asset at risk.

(e) High reliability and 0.8 hours per hour being generated from the PM and PdMs

- Monitor

(f) High reliability and many hours per hour being generated from the PM and PdMs.

- Redesign opportunities

11. Some corrective work can and will be done as part of the original PM and PdM or work order. Suggested guidelines for when a new work order should be used are as follows:
    (a) If the work required was not identified or is beyond the scope of the original PM or PdM work order and you are not prepared to do the additional work, or you do not have enough time to complete it in the time window that Operations has given to you.
    (b) If additional permitting is required.
    (c) If additional parts are required that will take longer to obtain than the time window Operations has given you.
    (d) If additional manpower is required to complete the task.
12. On a PdM to identify a failure mode with a short time from when you can first detect the impending failure till failure occurs, you may do many checks before identifying the problem. This would result in a low ratio of generated work to PdM work.

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SAMPLE CALCULATION

A given plant has 500 hours of corrective work that were identified during PM & PdM work. A total of 1,000 hours are spent performing the PM & PdM work.

PM & PdM Yield =
Corrective Work Identified from Preventive and Predictive Maintenance Work Orders (hours) / PM & PdM (hours)

PM & PdM Yield = 500 / 1,000
PM & PdM Yield = 0.5 hours per hour

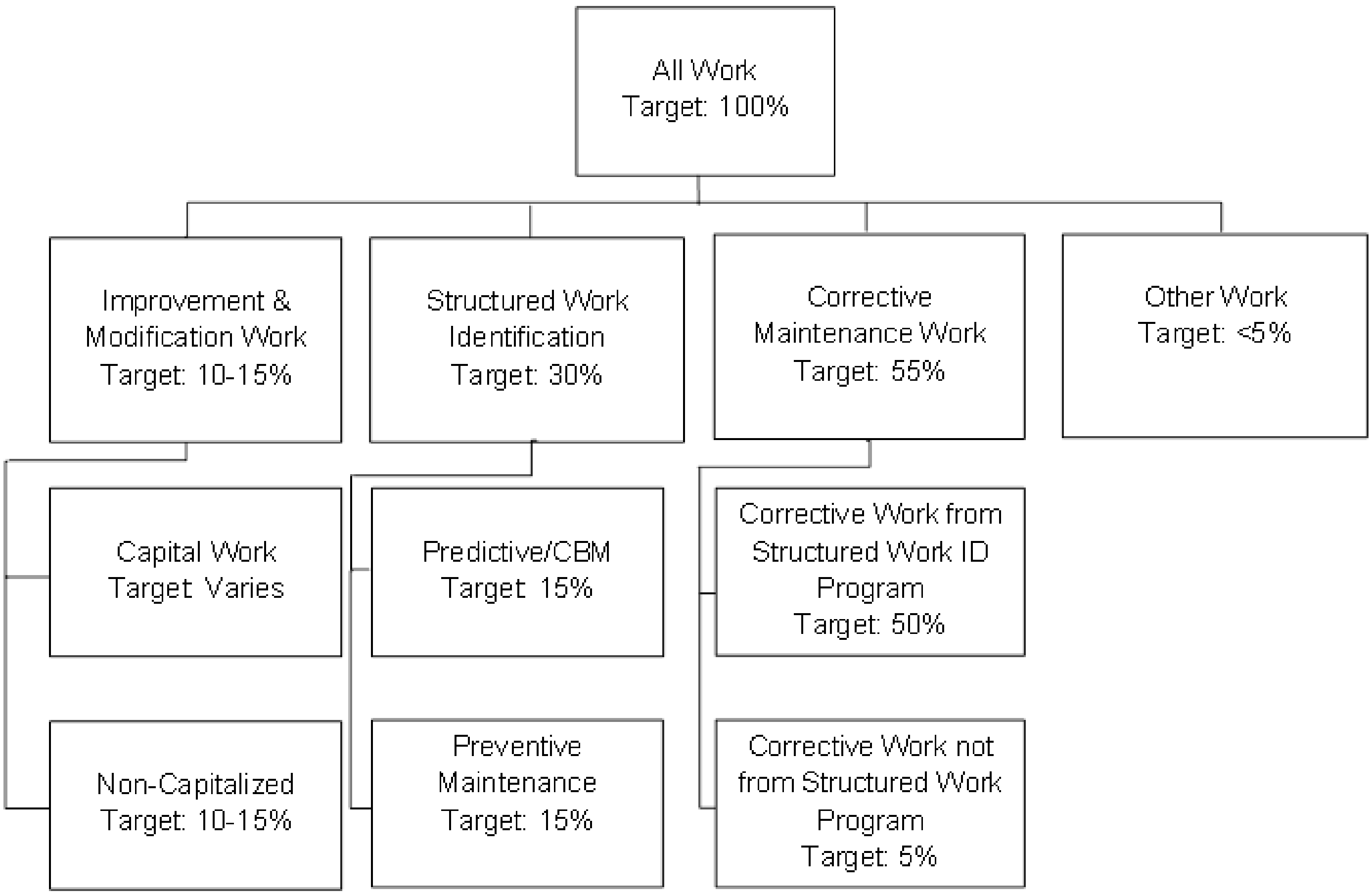


Figure 1. Maintenance Work Types

BEST-IN-CLASS TARGET VALUE

The best-in-class target value will vary from one plant to another; therefore, individuals should develop a maintenance results metric to use internally to monitor progress.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Smith, R. and Mobley, K (2008). *Rules of thumb for maintenance and reliability engineers*. Burlington, NY: Elsevier Butterworth Heinemann.

WORK MANAGEMENT METRIC

5.4.13 PREVENTIVE MAINTENANCE (PM) & PREDICTIVE MAINTENANCE (PDM) EFFECTIVENESS

Published on December 29, 2009

DEFINITION

This metric is a measure of the effectiveness of the corrective work that results directly from preventive maintenance (PM) and predictive maintenance (PdM) strategies. The measure is the amount of corrective work identified from PM/PdM work orders that was truly necessary. See Figure 1.

OBJECTIVES

The objective of this metric is to measure how effective the PM and PdM programs are at identifying potential failures. It is used to identify unnecessary tasks (e.g., those that do not add value) in order to optimize PM and PdM programs.

FORMULA

PM & PdM Effectiveness =
Number of PM & PdM Corrective Work Orders Necessary / Number of PM & PdM Corrective Work Orders Written

COMPONENT DEFINITIONS

Necessary Preventive Maintenance (PM) & Predictive Maintenance (PdM) Corrective Work Orders
Work where a defect or a potential failure was identified and corrected as a result of preventive maintenance (PM) and predictive maintenance (PdM) inspections or tasks.

Preventive Maintenance (PM) & Predictive Maintenance (PdM) Corrective Work Orders
All corrective work orders that are generated from a preventive maintenance (PM) or predictive maintenance (PdM) inspection or task.

Preventive Maintenance (PM)
Actions performed on a time- or machine-run-based schedule that detect, preclude or mitigate degradation of a component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level.

Predictive Maintenance (PdM)
An equipment maintenance strategy based on assessing the condition of an asset to determine the likelihood of failure and then taking appropriate action to avoid failure. The condition of equipment can be measured using condition monitoring technologies, statistical process control, equipment performance indicators or through the use of human senses.

Work Orders Necessary
Work where a defect or a potential failure was identified and corrected as a result of preventive maintenance (PM) and predictive (PdM) inspections or tasks.

QUALIFICATIONS

1. Time basis: Monthly
2. This metric is used by plant maintenance and reliability personnel.
3. It provides the best data when used to optimize PM/PdM tasks.
4. This measure can be separated to give either PM Effectiveness or PdM Effectiveness individually.
5. If a PM is scheduled too frequently, this measure will show a low PM effectiveness. A possible solution to optimize the PM is to extend the PM frequency.
6. A low PdM effectiveness could be the result of inadequate training of the PdM personnel (e.g., recommending corrective actions that are not necessary).
7. This metric should not be confused with SMRP Metric 5.4.12 which is a measure of the amount of corrective work that is “identified” from PM and PdM inspections and tasks.
8. PM effectiveness can be applied down to the asset level. If an asset has a low PM effectiveness, the PM strategy should be reviewed and revised.
9. PdM effectiveness can be used to identify issues with PdM technologies or strategies.
10. PdM effectiveness can be used to identify training opportunities for reliability personnel.
11. The best indicator of the effectiveness of PM and PdM work is the reliability of equipment. Reliability, however, is a lagging indicator.

12. Measuring work generated from PM and PdM work orders can be a leading indicator of the effectiveness of the program.
13. This metric should be tracked on critical equipment.
14. RCA is an effective tool for analyzing low PM and PdM effectiveness.
15. This metric can be used to track at either the work order or task level depending on the capability of the computerized maintenance management system (CMMS).

SAMPLE CALCULATION

In a given plant, the following five PM/PdM jobs occur during a given month.

1. A PM job based on a set time interval to replace bearings. The job is an eight hour job; however, once the machine is dismantled, it is determined that the bearings do not need to be replaced.
2. A PdM vibration route identifies misalignment in a machine train. To fix it requires four hours. Mechanics found that the train was out of alignment would consequently fail prematurely.
3. A PM job is scheduled to clean a heat exchanger to prevent fowling. The job is a 16 hour job and the assigned workers find the heat exchanger is fouled thereby reducing production capability.
4. A PdM job is scheduled based on an operator's check list. The operator recognized a low inlet pressure to a lube pump and recommended that the filter be changed. Time required is four hours. The filter is replaced but inlet pressure did not change. A root cause analysis (RCA) reveals that the problem is actually a faulty pressure gauge.
5. A PdM inspection is scheduled due to degradation of pump performance. The job required 12 hours. After dismantling, the impeller was found to be worn beyond allowable limits and, therefore, in need of replacement.

(Calculation continued on next page)

PM & PdM Effectiveness = Number of PM & PdM corrective work orders completed and deemed necessary/number of PM & PdM corrective work orders written

Number of Corrective Work tasks actually performed = 3 (Jobs 2, 3 and 5)
Number of Corrective Work Orders written = 5
PM/PdM Effectiveness = 3 jobs / 5 jobs = .6

The individual PM and PdM Effectiveness Measures are:
PM Effectiveness = 1 job / 2 jobs = 0.5
PdM Effectiveness = 2 jobs / 3 jobs = 0.67

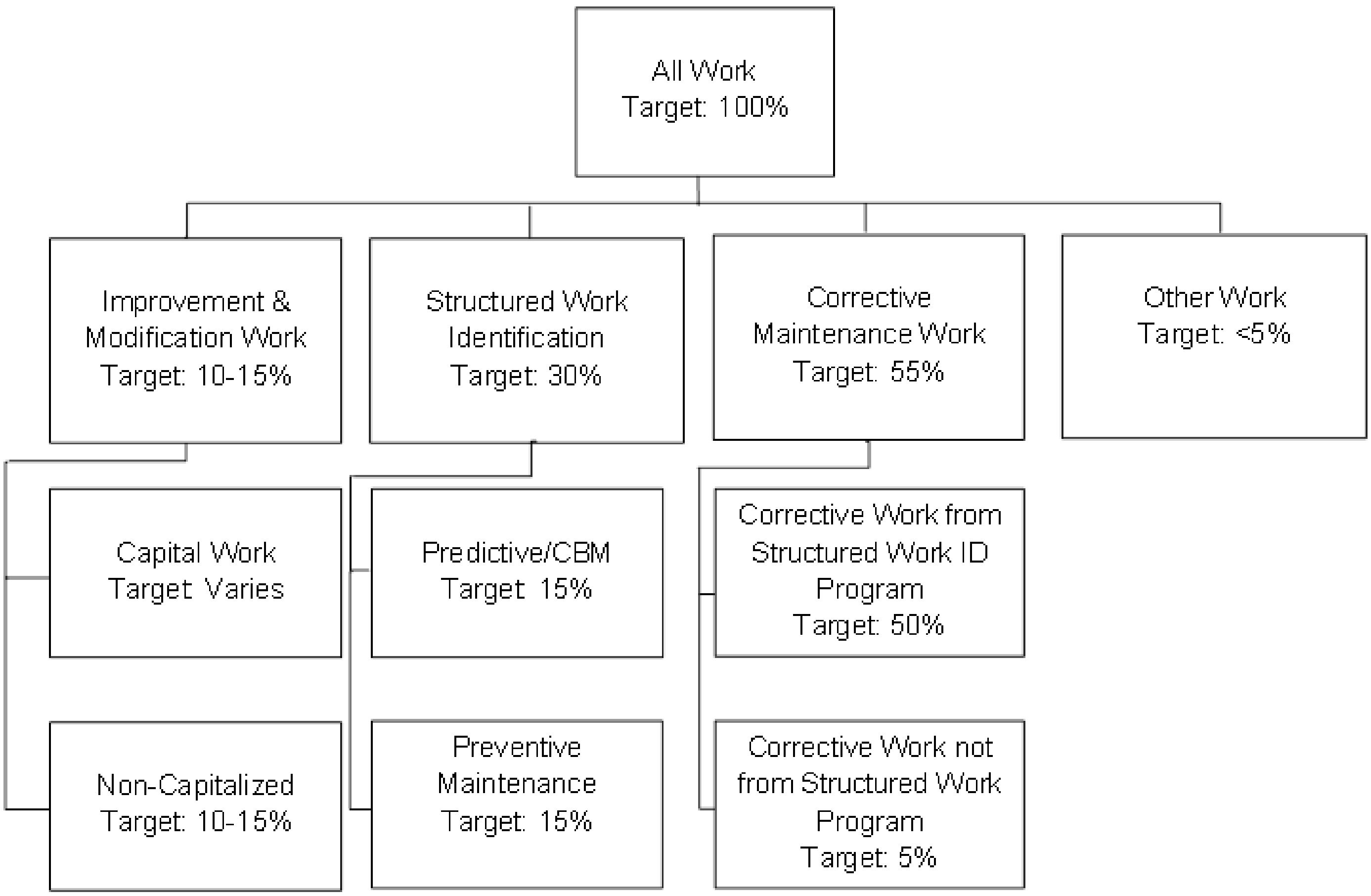


Figure 1. Maintenance Work Types

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

None

WORK MANAGEMENT METRIC

5.4.14 PREVENTIVE MAINTENANCE (PM) & PREDICTIVE MAINTENANCE (PDM) COMPLIANCE

Published on July 18, 2009
Revised on August 12, 2015

DEFINITION

This metric is a review of completed preventive maintenance (PM) and predictive maintenance (PdM) work orders, wherein the evaluation is against preset criteria for executing and completing the work.

OBJECTIVES

This metric summarizes PM and PdM work order execution and completion compliance.

FORMULA

PM & PdM Compliance =
PM & PdM work orders completed by due date / PM & PdM work orders due

PM & PdM work order compliance can be measured and reported different ways using different completion criteria.

1. A PM & PdM work order is considered completed on time if completed by the required date.
2. A PM & PdM work order is considered completed on time if completed by the required date + one day.
3. A PM & PdM work order is considered completed on time if completed by the required date + 20 % of the PM and PdM frequency up to a maximum of 28 days.

If a grace period is allowed for PM & PdM work order completion, the same completion criteria must be used consistently.

COMPONENT DEFINITIONS

Completion Date
The date that preventive maintenance (PM) or predictive maintenance (PdM) work order was certified complete and closed out in the maintenance management system (MMS) system.

Due Date
The required completion date of the preventive maintenance (PM) or predictive maintenance (PdM), including the grace period.

Execution Date
The date the preventive maintenance (PM) or predictive maintenance (PdM) work was executed on the asset or component.

Report Date Range
The selected calendar period in which work order completion occurs.

Required Date
The date when the preventive maintenance (PM) or predictive maintenance (PdM) work is scheduled to be completed.

QUALIFICATIONS

1. Time Basis: Monthly and annually
2. This metric is used by plant maintenance personnel to monitor PM and PdM work order compliance.
3. It required dates for PM and PdM completion should be based on the equipment manufacturer's recommendation or performance analysis supported by empirical data.
4. Performance should be trended and compared against predefined standards or targets.
5. Performance can be measured and reported by asset, for all assets or some subset thereof.
6. Typical grace periods based on fixed-frequency generated PMs and PdMs are shown in the table on the next page.

PM Frequency	Number of Days	+20% Grace Period* (days)
5 years	1,826	28 Max
2 years	730	28 Max
1 year	365	28 Max
6 months	182	28 Max
3 months	91	18
2 months	60	12
1 month	30	6
8 weeks	56	11
6 weeks	42	8
4 weeks	28	6
3 weeks	21	4
2 weeks	14	3
1 week	7	1

*Maximum of 28-days grace period

SAMPLE CALCULATION

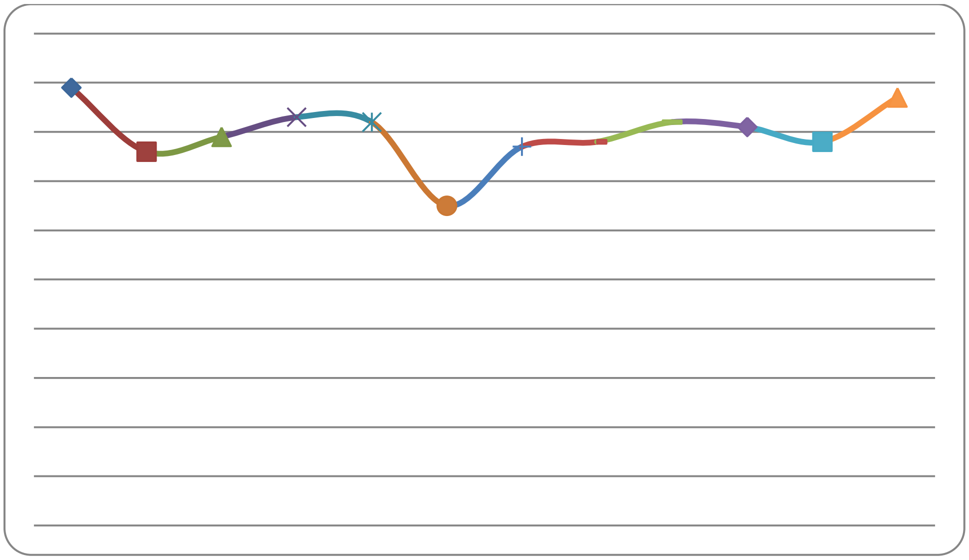
In a given month, 476 PMs and PdMs are due. There are 416 PMs and PdMs completed by the due date, with the remaining 70 overdue.

PM & PdM Compliance =
PM & PdM work orders completed by due date / PM & PdM work orders due

PM & PdM Compliance = 416 / 476
PM & PdM Compliance = 87.4%

An example of a basic PM & PdM Compliance table is shown below and a graph is shown on the next page.

Month	1	2	3	4	5	6	7	8	9	10	11	12
PM & PdM Compliance	89%	76%	79%	83%	82%	65%	77%	78%	82%	81%	78%	87%



BEST-IN-CLASS TARGET VALUE

Above 90%: Investigate non-compliance reasons, implement improvements, monitor results and look for improvement trend.

CAUTIONS

If a PM is completed early the next due date should be scheduled from the completed date.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Moore, R. (2004). *Making Common Sense Common Practice – Models for Manufacturing Excellence* (3rd ed), Burlington, NY: Elsevier Butterworth Heinemann.

Smith, R. and Mobley, K. R. (2003). *Industrial Machinery Repair: Best Maintenance Practices Pocket Guide*, Burlington, NY: Elsevier Butterworth Heinemann.

WORK MANAGEMENT METRIC

5.5.1 CRAFT WORKER TO SUPERVISOR RATIO

Published on June 15, 2009
Revised on August 12, 2015

DEFINITION

This metric is the ratio of maintenance craft workers to supervisors.

OBJECTIVES

This metric is used to measure the manpower workload of supervisors for comparison and benchmarking.

FORMULA

Craft Worker to Supervisor Ratio =
Total Number of Maintenance Craft Workers / Total Number of Supervisors

TNCW / TNS = Ratio

The result is expressed as a ratio (e.g., 15:1).

COMPONENT DEFINITIONS

Supervisor
A first-line leader who is responsible for work execution by craft workers.

Maintenance Craft Worker
The worker responsible for executing maintenance work orders (e.g., electrician, mechanic, PM/PdM technician, etc.).

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QUALIFICATIONS

1. Time basis: Annually.
2. This metric is used by maintenance and plant managers, human resources representatives and industrial engineers to understand the manpower workload of maintenance supervisors.
3. The ratio is calculated and used for the maintenance department and by individual supervisor for comparison and benchmarking.
4. Supervisors typically have additional responsibilities beyond supervising maintenance work execution (e.g., quality inspections, craft worker training, emergency work planning, etc.). These additional responsibilities must be considered when making comparisons.

SAMPLE CALCULATION

A given maintenance department has 78 craft workers and 6 supervisors.

Craft Worker to Supervisor Ratio =
Total Number of Maintenance Craft Workers / Total Number of Supervisors
Craft Worker to Supervisor Ratio = 78 / 6
Craft Worker to Supervisor Ratio = 13:1

A given supervisor has 12 mechanics and 2 welders assigned to his crew.
Craft Worker to Supervisor Ratio =
Total Number of Maintenance Craft Workers / Total Number of Supervisors
Craft Worker to Supervisor Ratio = (12 + 2) / 1
Craft Worker to Supervisor Ratio = 14:1

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BEST-IN-CLASS TARGET VALUE

Ratios	Performance Quartile
12:1	First Quartile (best)
15:1	Second Quartile
23:1	Third Quartile
24:1	Fourth Quartile (worst)

CAUTIONS

Include contractors in craft worker numbers if they report directly to craft supervisor. Do not include temporary contractors that have dedicated supervision supplied.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Hawkins, B. & Smith, R. (2004). *Lean Maintenance–Reduce Costs Improve Quality, and Increase Market Share,* Burlington, NY: Elsevier Butterworth Heinemann.

Katsilometes, J. D. (2004). *How Good is My Maintenance Program?* Cleveland Cliffs Inc. Cleveland, Ohio

Kister, T. (2006*). Moving Misguided Planner to Effective Planner;* Life Cycle Engineering, Presented at MARTS Conference 2006. Chicago, IL.

Solomon Associates. (2012). *Practices Employed by Best Performing Companies*. Dallas, TX. Presented at 20th Annual SMRP Conference 2012. Orlando, FL.

Wireman, T. (1990). *World Class Maintenance Management.* New York, NY: Industrial Press

WORK MANAGEMENT METRIC

5.5.2 CRAFT WORKER TO PLANNER RATIO

Published on August 19, 2009
Revised on August 12, 2015

DEFINITION

This metric is the ratio of maintenance craft workers to planners.

OBJECTIVES

This metric is used to measure the manpower planning workload of planners for comparison and benchmarking. This ratio identifies the level of work planning activities necessary to maintain a backlog of planned maintenance work.

FORMULA

Craft Worker to Planner Ratio =
Total Number of Maintenance Craft Workers / Total Number of Planners

CWPR = TNMC / TNP

The result is expressed as a ratio (e.g., 30:1).

COMPONENT DEFINITIONS

Maintenance Craft Worker
The worker responsible for executing maintenance work orders (e.g., electrician, mechanic, PM/PdM technician, etc.).

Planned Work
Work that has gone through a formal planning process to identify labor, materials, tools, and safety requirements. This information is assembled into a job plan package and communicated to craft workers prior to the start of the work.

Planner
A formally trained maintenance professional who identifies labor, materials, tools and safety requirements for maintenance work orders. The planner assembles this information into a job plan package and communicates it to the maintenance supervisor and/or craft workers prior to the start of the work.

QUALIFICATIONS

1. Time basis: Annually at a minimum, or as required
2. This metric is used by maintenance and plant managers, human resources representatives and industrial engineers to understand the manpower planning workload of maintenance planners.
3. The ratio is calculated and used for the maintenance department and for individual planners for comparison and benchmarking.
4. This metric is typically normalized to a 40-hour work week.
5. A planner may have duties such as expediting or overseeing capital repairs that are not classified as planning. Only planning hours should be used when calculating this metric (e.g., equivalent planner).
6. The best-in-class target assumes that planners are dedicated to the planning process, professional (e.g., trained), and 75% of work is proactive (limited to 25% urgent response).

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SAMPLE CALCULATION

A given maintenance department has 78 craft workers and 2 planners.

Craft Worker to Planner Ratio =
Total Number of Maintenance Craft Workers / Total Number of Planners
Craft Worker to Planner Ratio = 78 / 2
Craft Worker to Planner Ratio = 39:1

A given planner plans work for 28 mechanics, 3 welders, 2 machinists and 1 heavy equipment operator.

Craft Worker to Planner Ratio =
Total Number of Maintenance Craft Workers / Total Number of Planners
Craft Worker to Planner Ratio = (28 + 3 + 2 + 1) / 1
Craft Worker to Planner Ratio = 34:1

BEST-IN-CLASS TARGET VALUE

20:1 (craft worker to planner)

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Life Cycle Engineering, (2005). *Maintenance Excellence for Maintenance Leaders*. Educational Program

Palmer, R. D. (1999). *Maintenance Planning and Scheduling Handbook*. New York City, NY: McGraw-Hill.

Solomon Reliability and Maintenance Benchmarking Study (2013)

WORK MANAGEMENT METRIC

5.5.3 DIRECT TO INDIRECT MAINTENANCE PERSONNEL RATIO

Published on April 16, 2009
Revised on August 24, 2016

DEFINITION

This metric is the ratio of the maintenance personnel who are actively doing the maintenance work (direct) to the maintenance personnel supporting the maintenance work (indirect). Direct personnel include those workers in the maintenance department that repair, maintain, modify or calibrate equipment. Indirect personnel support the maintenance work with administration, planning, stores, condition monitoring and supervision.

OBJECTIVES

The objective of this metric is to analyze the balance of direct and indirect maintenance personnel for the purposes of trending and benchmarking as a methodology for managing staffing levels of the organization.

FORMULA

Direct to Indirect Maintenance Personnel Ratio =
Number of Direct Maintenance Personnel / Number of Indirect Maintenance Personnel

If including contract labor:
Direct to Indirect Maintenance Personnel Ratio =
(Number of Direct Maintenance Personnel + Number of Direct Contract Maintenance Personnel) / (Number of Indirect Maintenance Personnel + Indirect Contract Maintenance Personnel)

Expressed as a ratio X: Y, where X is “Direct” and Y is “Indirect”.

COMPONENT DEFINITIONS

Direct Contract Maintenance Personnel

Maintenance workers who are not company employees, but are hired or provided by an outside company to perform actual maintenance tasks, such as corrective and preventive maintenance. Examples include contract mechanics, electricians and hourly technicians.

Direct Maintenance Personnel

Maintenance employees assigned to perform actual maintenance tasks, such as corrective and preventive maintenance. Examples include mechanics, electricians, pipe fitters, mobile equipment operators and hourly technicians.

Indirect Contract Maintenance Personnel

Maintenance personnel are maintenance workers, who are not company employees, but hired or provided by an outside company to support the contracted maintenance services, and are not directly performing maintenance work. Examples include contract supervision, engineering, maintenance planning and scheduling, inspection, clerical, etc.

Indirect Maintenance Personnel

Maintenance employees required to support the overall maintenance operation, but not directly performing maintenance work. These personnel are generally charged to an overhead account. Examples include supervision, engineering, maintenance planning and scheduling, clerical, etc.

Maintenance Contract Employees

All personnel, salaried and hourly, direct and indirect, who are hired or provided by an outside company and are responsible for executing work assignments pertaining to the maintenance of physical assets and components.

Maintenance Employees

All personnel, salaried and hourly, direct and indirect, who are responsible for executing work assignments pertaining to the maintenance of physical assets and components. Same as internal maintenance employee.

QUALIFICATIONS

1. Time basis: Annually and semi-annually
2. This metric is used by maintenance executives, managers and supervisors.

3. This metric provides the best data when used to measure efficiency and effectiveness of the maintenance operation and to determine whether resource levels are appropriate.
4. Direct labor is generally associated with the manufacturing of the product or service, and their labor costs are captured on work orders.
5. Indirect labor is generally associated with an overhead account, and this labor is not captured on a work order.
6. This metric should not include operations personnel.
7. In some cases, contractors as full time equivalents (FTEs) will be included. When including contractors, include both indirect and direct contract personnel as FTEs. When determining FTEs, calculate the number of FTEs using the same time basis for all personnel (e.g., monthly, annually, etc.)

SAMPLE CALCULATION

Without Contract Personnel:

In this example, the plant does not use any contract labor. The following table is a list of maintenance personnel with headcount by position and/or role:

Indirect		**Direct**	
Position	Number	Position	Number
Maintenance Manager	1	Mechanical Technician	66
Mechanical Supervisors	8	Electrical Technicians	25
I&E Supervisors	7	Lubrication Technicians	5
Trainers	4	Analyzer Technicians	15
Maintenance Engineers	15	Refrigeration Technicians	6
Base Inspectors	5	Instrument Technicians	45
Condition Monitoring Analysts	5	Millwrights	12
Planners	7		
Schedulers	2		
Materials Coordinator	2		
Clerk	2		
Designers	5		
Tool Room Attendant	2		
Maintenance Analyst	1		
Total	**66**		**174**

Direct to Indirect Maintenance Personnel Ratio =
Number of Direct Maintenance Personnel / Number of Indirect Maintenance Personnel

Direct to Indirect Maintenance Personnel Ratio = 174 / 66
Direct to Indirect Maintenance Personnel Ratio = 2.6:1 or 2.6

With Contract Personnel:
In this example, the plant does use contract labor. Based on the plant's analysis, the plant calculates that there are 65 (FTE) working at the plant on various maintenance activities.
The following table is a list of maintenance personnel with headcount by position and/or role:

Indirect		**Direct**	
Position	Number	Position	Number
Maintenance Manager	1	Mechanical Technician	66
Mechanical Supervisors	8	Electrical Technicians	25
I&E Supervisors	7	Lubrication Technicians	5
Trainers	4	Analyzer Technicians	15
Maintenance Engineers	15	Refrigeration Technicians	6
Base Inspectors	5	Instrument Technicians	45
Condition Monitoring Analysts	5	Millwrights	12
Planners	7	Contract Full Time Equivalents	65
Schedulers	2		
Materials Coordinator	2		
Clerk	2		
Designers	5		
Tool Room Attendant	2		
Maintenance Analyst	1		
Total	**66**		**239**

Direct to Indirect Maintenance Personnel Ratio =
Number of Direct Maintenance Personnel / Number of Indirect Maintenance Personnel

Direct to Indirect Maintenance Personnel Ratio = 239 / 66
Direct to Indirect Maintenance Personnel Ratio = 3.6:1 or 3.6

FTE Calculation: The method to determine the FTE for contractors will depend on how the organization tracks contractor labor. The most accurate method is to track contractor hours and then the FTE can be easily determined from dividing the total hours over a period, by the possible hours of a single worker for that period (typically one year).

For example, total contractor annual direct hours equal 124,800 and possible hours for a single worker over one year equal 1,920, then:

Direct FTE = 124,800 hrs. / 1,920 hrs. = 65

If your organization tracks contractor labor by cost, then the method is to divide the total contractor direct labor cost by the labor cost of a single worker for the given period. For example, total contractor annual direct cost equals $5,590,000 and the labor cost for a single worker over one year equals $86,000, then:

Direct FTE = $5,590,000 / $86,000 = 65

The important thing here for the cost calculation method is to ensure that cost represent labor cost and not any materials or equipment.

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee recommends a target range of 2:1 to 3:1 for all maintenance department personnel. A higher ratio is achievable and acceptable for newer, technically advanced facilities or processes. A lower value is acceptable for older assets due to more support intensive equipment or where predictive inspection techniques may not be an available alternative. We encourage this metric with the monitoring of other condition based maintenance metrics for further evaluation of the total condition based maintenance program.

CAUTIONS

The metric provides the best data when used to measure efficiency and effectiveness of the maintenance department and to determine whether resource levels are appropriate.

Direct labor is generally associated with the manufacturing of the product or service; their labor costs are usually captured on work orders.

Indirect labor is generally associated with an overhead account; this labor is usually not captured on work orders.

This metric should not include operations personnel.

In some cases, contractors as full-time equivalents (FTEs) will be included. When including contractors, include both indirect and direct contract personnel as FTEs. When determining

FTEs, calculate the number of FTEs using the same time basis for all personnel (e.g., monthly, annually, etc.)

HARMONIZATION

This metric and its supporting definitions are similar or identical to the indicator 03 in standard EN15341.

Note 1: Numerator and denominator are reversed in the two metrics.

Note 2: The SMRP metric is expressed as a ratio, while the EN indicator is expressed as a percentage.

Note 3: The SMRP metric can be calculated with the inclusion of contractors. The EN 15341 calculates only "internal" or "maintenance employees."

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the 03 indicator. Additional information is available in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library

REFERENCES

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WORK MANAGEMENT METRIC

5.5.4 INDIRECT MAINTENANCE PERSONNEL COST

Published April 26, 2009

DEFINITION

This metric is the cost incurred for indirect maintenance personnel for the period, expressed as a percentage of the total maintenance cost for the period.

OBJECTIVES

This metric enables management to measure the contribution of indirect maintenance labor costs to total maintenance costs. This value can then be compared to industry benchmarks and analyzed for cost reduction opportunities.

FORMULA

Indirect Maintenance Personnel Cost (%) =
Indirect Maintenance Personnel Cost x 100 / Total Maintenance Cost

COMPONENT DEFINITIONS

Indirect Maintenance Personnel
Maintenance employees required to support the overall maintenance operation, but not directly performing maintenance work. These personnel are generally charged to an overhead account. Examples include supervision, engineering, maintenance planning and scheduling, clerical, etc.

Indirect Maintenance Personnel Cost
All maintenance labor costs, both straight, overtime and payroll added cost, such as taxes or insurance contributions. Does not include labor for these individuals that is used for capital expenditures or contractor labor cost.

Total Maintenance Cost
The total expenditures for maintenance labor, including maintenance performed by operators such as total productive maintenance (TPM), materials, contractors, services and resources. Includes all maintenance expenses for outages, shutdowns or turnarounds, as well as normal

operating times. Also includes capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include capital expenditures for plant expansions or improvements.

QUALIFICATIONS

1. Time Basis: Annually, but can be measured quarterly as well.
2. This metric is useful for developing trends in the distribution of maintenance spending.
3. It is also useful for comparing the organization's performance relative to industry benchmarks.
4. This metric is used by corporate managers, plant managers, maintenance managers, HR managers and vice-presidents to compare different sites.
5. The amount of support and supervision staff required is a direct reflection of the qualifications of the maintenance staff in the field, the qualifications of the support staff or the maintenance processes. This value may demonstrate a need for attention in the area of maintenance qualifications, support staff or maintenance processes.

SAMPLE CALCULATION

Following are the categories of maintenance costs used last year at the site:

Indirect Maintenance Personnel Costs	$2,320,000
Internal Maintenance Labor	$8,144,000
Contractor Labor	$1,125,000
Corporate Resource Allocation	$ 100,000
Annual Equipment Maintenance Contracts	$ 96,000
Janitorial Service Contracts	$ 380,000
Maintenance Materials	$9,992,000
Annual maintenance costs	$22,157,000

Indirect Maintenance Personnel Cost = $2,320,000 / $22,157,000 = 10.47%

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee was unable to find any target ranges, minimum/maximum values, benchmarks or other references for target values for this metric. SMRP will update this metric should future work help establish targets for this metric. While no target values are currently available, SMRP encourages plants to use this metric to help manage the maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric and its supporting definitions are similar or identical to the indicator E13 in standard EN15341.

Note 1: The difference between this metric and indicator E13 in standard EN15341 is that EN 15341 has a broader definition and includes depreciation of maintenance owned equipment and facilities in total maintenance cost (office, workshop and warehouse).

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the E13 indicator.

Additional information is available in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

REFERENCES

Jones, J. V. (2007). Supportability engineering handbook – Implementation, measurement & management. New York, NY: McGraw Hill.

WORK MANAGEMENT METRIC

5.5.5 INTERNAL MAINTENANCE EMPLOYEE COST

Published on April 16, 2009
Revised on August 24, 2016

DEFINITION

This metric is the total burdened cost incurred for plant maintenance employees for the period, expressed as a percentage of the total maintenance cost for the period.

OBJECTIVES

The objective of this metric is to enable management to monitor the relationship of maintenance labor costs to total maintenance costs. It can be used to measure the ratio of maintenance employee costs to contract maintenance employee cost.

FORMULA

Internal Maintenance Employee Cost (%) =
[Internal Maintenance Employee Cost ($) / Total Maintenance Cost ($)] × 100

COMPONENT DEFINITIONS

Total Internal Maintenance Employee Labor Costs

Includes all internal maintenance labor costs (including benefits), both straight time and overtime, for all direct and indirect maintenance employees. Includes maintenance labor costs for normal operating times, as well as outages/shutdowns/turnarounds. Also includes labor for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Includes the cost for maintenance work performed by operators. Does not include labor used for capital expenditures for plant expansions or improvements or contractor labor cost. Does not include janitorial cost or other similar costs not associated with the maintenance of plant equipment.

Total Maintenance Cost

The total expenditures for maintenance labor, including maintenance performed by operators such as total productive maintenance (TPM), materials, contractors, services and resources.

Includes all maintenance expenses for outages, shutdowns or turnarounds, as well as normal operating times. Also includes capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include capital expenditures for plant expansions or improvements.

QUALIFICATIONS

1. Time basis: Annually and quarterly
2. This metric is used by corporate managers, plant managers, maintenance managers and human resources managers to compare different sites
3. It is useful for developing trends in the distribution of maintenance spending.
4. This metric is also useful for comparing the organization's performance relative to industry benchmarks.

SAMPLE CALCULATION

For a given plant, the maintenance costs for a given year are as follows:

Internal Maintenance Labor (including benefits)	$8,144,000
Maintenance Staff Overhead (Supervisors, Planners, etc.)	$2,320,000
Contractor Labor	$1,125,000
Annual Equipment Maintenance Contracts	$ 96,000
Janitorial Service Contracts	$ 380,000
Maintenance Materials	$9,992,000
Total Maintenance Cost	**$22,057,000**

Internal Maintenance Employee Cost (%) =
[Internal Maintenance Employee Cost ($) / Total Maintenance Cost ($)] × 100

Internal Maintenance Employee Cost (%) =
[($8,144,000 + $2,320,000) / $22,057,000] × 100
Internal Maintenance Employee Cost (%) = [$10,464,000 / $22,057,000] × 100
Internal Maintenance Employee Cost (%) = 0.474 × 100
Internal Maintenance Employee Cost (%) = 47.4%

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee was unable to find any target ranges, minimum/maximum values, benchmarks or other references for target values for this metric. SMRP will update this metric as appropriate should future work help establish targets for this metric. While no target values are currently available, SMRP encourages plants to use this metric to help manage the maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

The SMRP Best Practices Committee strongly recommends a cautious approach in using this metric for comparison between facilities or organizations since there are no benchmark targets defined for this metric.

HARMONIZATION

This metric and its supporting definitions are similar or identical to the indicator E8 in standard EN 15341.

Note 1: The difference between this metric and indicator E8 in standard EN15341 is that EN 15341 has a broader definition and includes depreciation of maintenance owned equipment and facilities in total maintenance cost.

Note 2: Both EN 15341 E8 and the SMRP metric 5.5.5 include internal maintenance personnel costs. Internal maintenance personnel cost includes blue collar, managerial, support and supervisory personnel.

Note 3: The SMRP term internal maintenance employee cost is equivalent to the EN 15341 term total internal personnel cost spent in maintenance.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the E8 indicator. Additional information is available in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

REFERENCES

Marshall Institute (2000). Establishing meaningful measures of maintenance performance. Raleigh, N.C.

WORK MANAGEMENT METRIC

5.5.6 CRAFT WORKER ON SHIFT RATIO

Published on June 27, 2009
Revised on August 12, 2015

DEFINITION

This metric is the ratio of the number of maintenance craft workers on shift whose primary function is to respond to unexpected failures versus the total number of maintenance craft workers.

OBJECTIVES

This metric is an indirect measurement of equipment reliability since frequent unexpected failures require craft workers on shift to expedite repairs. Trending the number of craft workers on shift can also help identify maintenance issues. This can be used to benchmark with other companies or between departments within the same plant.

FORMULA

Craft Worker on Shift Ratio =
Total Number of Maintenance Craft Workers on Shift / Total Number of Maintenance Craft Workers

The result is expressed as a ratio (e.g., 1:6).

This formula can also be phrased as CWS= TNMCS / TNMC.

COMPONENT DEFINITIONS

Maintenance Craft Worker
The worker responsible for executing maintenance work orders (e.g., electrician, mechanic, PM/PdM technician, etc.).

On Shift
Maintenance craft workers who rotate with or who are assigned work hours aligned with a production shift are considered "on shift." Maintenance craft workers on shift typically work on

emergency work and are not identified with the main group of maintenance craft workers that work day shift.

QUALIFICATIONS

1. Time basis: Monthly
2. This metric is used by plant management as an indicator of the reliability of production assets.
3. Trending the number of craft workers on shift may help identify maintenance issues on the off shifts.
4. Maintenance craft workers called in to work outside their normal shift are not considered on shift.

SAMPLE CALCULATION

A given maintenance department has 24 mechanics with three on shift, eight Electricians with two on shift and four instrumentation technicians with one on shift.

Craft Worker on Shift Ratio = Total Number of Maintenance Craft Workers On Shift / Total Number of Maintenance Craft Workers

Craft Worker on Shift Ratio = (3 + 2 + 1) / (24 + 8 + 4)
Craft Worker on Shift Ratio = 6 / 36
Craft Worker on Shift Ratio = 1:6

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee was unable to find any target ranges, minimum/maximum values, benchmarks or other references to target values for this metric. However, industry generally recognizes that craft workers on shift are utilized primarily for maintenance coverage in cases of mechanical breakdowns and emergencies. When craft workers on shift are used for emergency coverage, the number of craft workers on shift should be minimized with the goal to eliminate emergencies and craft workers assigned to a shift (e.g., target = 0).

If craft workers on shift are utilized primarily for planned and scheduled work, required for regulatory reasons or some other reason other than standby for possible equipment failures, then the number of craft workers on shift should be based on the backlog of shift required work, and their time schedule appropriately.

SMRP will update this metric as appropriate should future work help establish targets for this metric.

CAUTION

There are no cautions identified at this time.

HARMONIZATION

This metric and its supporting definitions are similar or identical to EN 15341 indicator O10.

Note 1: On call craft workers are excluded from the calculation for both metrics/indicators.

Note 2: SMRP Metric calculates the formula as a ratio. EN 15341 indicator calculates the formula as percentage.

Note 3: The term maintenance craft worker is similar to EN 15341: direct maintenance personnel.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the O10 indicator. Additional information is available in the document *Global Maintenance and Reliability Indicators* available for purchase in the SMRP Library.

REFERENCES

Approved by consensus of SMRP Best Practice Committee.

WORK MANAGEMENT METRIC

5.5.7 OVERTIME MAINTENANCE COST

Published on May 13, 2009
Revised on April 17, 2013

DEFINITION

This metric is the cost of overtime maintenance labor used to maintain assets divided by the total cost of maintenance labor used to maintain assets, expressed as a percentage.

OBJECTIVES

This metric is used to determine whether the permanent maintenance workforce is performing effectively and appropriately staffed for the maintenance workload.

FORMULA

Overtime Maintenance Cost (%) =
[Overtime Maintenance Labor Cost ($) / Total Maintenance Labor Cost ($)] × 100

COMPONENT DEFINITIONS

Overtime Maintenance Labor Cost
The cost of any hours worked beyond the standard work period or shift (e.g., eight hours per day or 40 hours per week) multiplied by the labor rate. Includes production incentives, but not profit sharing. Includes labor costs for normal operating times as well as for outages, shutdowns or turnarounds. Also includes labor cost for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include labor cost used for capital expenditures for plant expansions or improvements. Typically, overtime labor cost does not include temporary contractor labor overtime cost.

Overtime Maintenance Labor Hours
Any hours beyond the normal standard work period or shift (e.g., eight hours per day or 40 hours per week). Include overtime maintenance labor hours for normal operating times as well as outages, shutdowns or turnarounds. If operator hours spent on maintenance activities are

captured, they should be included in the numerator and denominator of all applicable metrics. Overtime maintenance labor hours include labor hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. It does not include labor hours used for capital expenditures for plant expansions or improvements. Typically, overtime maintenance labor hours does not include temporary contractor labor overtime hours.

Total Maintenance Labor Cost
Expressed in dollars, including overtime. Total cost includes all maintenance labor hours multiplied by the labor rate, plus any production incentive, but not profit sharing. Includes maintenance labor costs for normal operating times, as well as outages, shutdowns or turnarounds. Includes labor for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include labor used for capital expenditures for plant expansions or improvements. Typically, does not include temporary contractor labor cost.

QUALIFICATIONS

1. Time basis: Typically calculated on a monthly basis.
2. This metric is used by maintenance managers, maintenance supervisors and human resources managers to evaluate the need for additional resources.
3. Complementary metrics include SMRP Metric 5.6.1, SMRP Metric 5.4.1, SMRP Metric 5.5.71, SMRP Metric 5.5.8 and SMRP Metric 4.1.
4. If a contractor is used as permanent onsite maintenance, their costs should be included.
5. It may be difficult to separate operator-based maintenance labor cost.
6. Abnormally high levels of overtime during turnarounds may skew routine overtime maintenance cost.
7. Cost can be expressed in any currency as long as the same currency is used for comparison purposes.

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SAMPLE CALCULATION

If overtime maintenance labor cost in a given month is $12,500 and the total maintenance labor cost is $250,000 for this same month, overtime maintenance cost would be:

Overtime Maintenance Cost (%) =
[Overtime Maintenance Labor Cost ($) / Total Maintenance Labor Cost ($)] × 100

Overtime Maintenance Cost (%) = [$12,500 / $250,000] × 100
Overtime Maintenance Cost (%) = 0.05 × 100
Overtime Maintenance Cost (%) = 5%

BEST-IN-CLASS TARGET VALUE

Less than (<) 5%

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Hawkins, B. & Smith, R. (2004). *Lean maintenance–reduce costs improve quality, and increase market share*. Burlington, NY: Elsevier Butterworth Heinemann.

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Wireman, T. (1998). *Developing performance indicators for managing maintenance.* New York, NY Industrial Press.

WORK MANAGEMENT METRIC

5.5.8 OVERTIME MAINTENANCE HOURS

Published on April 16, 2009

DEFINITION

This metric is the number of overtime maintenance labor hours used to maintain assets, divided by the total maintenance labor hours to maintain assets, expressed as a percentage.

OBJECTIVES

This metric is used to determine whether the permanent maintenance workforce is performing effectively and appropriately staffed for the maintenance workload.

FORMULA

Overtime Maintenance Hours (%) =
(Overtime Maintenance Labor Hours / Total Maintenance Labor Hours) × 100

COMPONENT DEFINITIONS

Overtime Maintenance Labor Hours

Any hours beyond the normal standard work period or shift (e.g., eight hours per day or 40 hours per week). Include overtime maintenance labor hours for normal operating times as well as outages, shutdowns or turnarounds. If operator hours spent on maintenance activities are captured, they should be included in the numerator and denominator of all applicable metrics. Overtime maintenance labor hours include labor hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. It does not include labor hours used for capital expenditures for plant expansions or improvements. Typically, overtime maintenance labor hours does not include temporary contractor labor overtime hours.

Total Maintenance Labor Hours

Expressed in hours and includes all maintenance labor hours for normal operating times as well as outages, shutdowns and turnarounds. If operator hours spent on maintenance activities are captured, they should be included in the numerator and denominator of all applicable metrics.

Include labor hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include labor hours used for capital expansions or improvements. Typically, total maintenance labor hours do not include temporary contractor labor hours.

QUALIFICATIONS

1. Time basis: Typically calculated on a monthly basis.
2. This metric is used by maintenance managers, maintenance supervisors and human resources managers to evaluate the need for additional resources.
3. Complementary metrics include SMRP Metric 5.6.1, SMRP Metric 5.4.1, SMRP Metric 5.5.71, SMRP Metric 5.5.7 and SMRP Metric 4.1.
4. If a contractor is used as permanent onsite maintenance, their hours should be included.
5. It may be difficult to separate operator-based maintenance labor hours.
6. Abnormally high levels of overtime during turnarounds may skew routine overtime maintenance hours.

SAMPLE CALCULATION

In a given month, overtime maintenance labor hours are 500 and the total maintenance labor hours are 10,000 for the same month, overtime maintenance hours would be:

Overtime Maintenance Hours (%) =
(Overtime Maintenance Labor Hours / Total Maintenance Labor Hours) × 100

Overtime Maintenance Hours (%) = (500 hours / 10,000 hours) × 100
Overtime Maintenance Hours (%) = 0.5 × 100
Overtime Maintenance Hours (%) = 5%

BEST-IN-CLASS TARGET VALUE

10% with adherence to cautions outlined below; otherwise less than (<) 5%

CAUTIONS

Because of the ability to run high levels of inefficient overtime it is imperative that the overtime maintenance hours best practice target of 10% be applied in conjunction with other key best practice metrics. Failure to follow this approach is likely to result in poor overtime performance, and in that case the best practice target to be applied is <5%. The following criteria must be applied when using the best practice target of 10%:

1. Low levels of reactive work are required. Best practice reactive work less than (<)10% (SMRP Metric 5.4.1).
2. The vast majority of overtime should be planned well in advance of execution. Best practice planned work greater than (>) 90% (SMRP Metric 5.3.1) Planned work on overtime >90%.
3. High levels of schedule compliance for all craft manpower must be achieved. Best practice schedule compliance hours greater than (>) 90% (SMRP Metric 5.4.3).
4. Overtime used in outages (turnarounds) is to be planned and scheduled as part of overall project plan.

HARMONIZATION

This metric and its supporting definitions are similar or identical to the indicator O21 in standard EN 15341.

Note 1: Both SMRP and EN15342 calculate only direct personnel.

Note 2: Permanent contractors on site are included in the calculation of SMRP Metric 5.5.8. EN 15341 excludes contractors.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the O21 indicator.

Additional information is available in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

REFERENCES

Dale, B. (2006). World class maintenance management lecture notes from training course. Marshall Institute, Raleigh, NC.

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WORK MANAGEMENT METRIC

5.5.31 STORES INVENTORY TURNS

Published on August 1, 2009
Revised on August 12, 2015

DEFINITION

This metric is a measure of how quickly inventory is flowing through the storeroom inventory system. It can be applied to different categories of inventory, including spares and operating.

OBJECTIVES

This metric is used to measure the appropriateness of storeroom inventory levels.

FORMULA

Stores Inventory Turns =
Value of stock purchased over a set period of time / Value of stock on hand
The unit of measure is inventory turns per unit of time.

This formula can also be expressed as SIT (# / Time) = VSP / VSH.

COMPONENT DEFINITIONS

Value of Stock on Hand
The current value of the stock in inventory.

Value of Stock Purchased
The value of the inventory items purchased in the period for which the metric is being calculated.

QUALIFICATIONS

1. Time Basis: Monthly
2. This metric is used by storeroom, purchasing and finance management.

3. Due to variation in the stock replenishment process, this metric should be measured over a time period that allows anomalies in the purchasing cycle to be normalized.
4. This metric is best used with other indicators (e.g., SMRP Metric 5.5.33) that provide a complete picture of storeroom inventory.
5. This metric should be trended in order to capture changes in storeroom inventory management practices.
6. This metric can be used on subsets of the inventory to see the specific behavior of different classes of inventory items (e.g., power transmission, electrical, operating supplies, spare parts, etc.).
7. When used in conjunction with SMRP Metric 5.5.33, a low stock out and low turn ratio would suggest that inventory levels are too high. An effective storeroom must manage risk at an acceptable level and balance this against working capital. The optimum turn ratio will be different for different classes of parts and will depend on the amount of risk a facility is willing to take. A high turn ratio on spare parts could indicate a reliability issue and/or reactive maintenance culture.

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SAMPLE CALCULATION

A given storeroom has current values and purchases over the previous twelve months as follows:

Total storeroom inventory value is $7,241,296
Total of all storeroom purchases during this period is $15,836,351
Total spare parts inventory value is $3,456,789
Total of all spare parts purchases during this period is $5,123,456
Total operating supplies inventory value is $1,567,890
Total of all operating supplies purchases during this period is $9,345,678

Stores Inventory Turns = Value of stock purchased/Value of stock on hand
Stores Inventory Turns (total inventory) = $15,836,351 / $7,241,296
Stores Inventory Turns (total inventory) = 2.19
Stores Inventory Turns (spare parts) = $5,123,456 / $3,456,789
Stores Inventory Turns (spare parts) = 1.48
Stores Inventory Turns (operating supplies) = $9,345,678 / $1,567,890
Stores Inventory Turns (operating supplies) = 5.96

BEST-IN-CLASS TARGET VALUE

Total inventory greater than (>) 1.0

Inventory without critical spares greater than (>) 3.0

CAUTIONS

Since inventory can be divided in several categories including total inventory, insurance spares, critical spares, consumables, etc., categories must be well defined and standardized between facilities to make comparisons accurate.

HARMONIZATION

This metric and its supporting definitions are similar or identical to EN 15341 indicator E12.

Note 1. The EN 15341 indicator includes only the inventory turns of spare parts in the calculation. The SMRP Metric 5.5.31 calculates the value of the spare parts + operating parts

(MRO). However, the SMRP Metric 5.5.31 offers the possibility to calculate spare parts separately.

Note 2: If the SMRP 5.5.31 calculation is applied only to the spare parts in stock, excluding operating parts, then the metrics are identical.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the E12 indicator. Additional information is available in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

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WORK MANAGEMENT METRIC

5.5.32 VENDOR MANGED INVENTORY

Published on April 16, 2009

DEFINITION

This metric is the ratio of the number of stocked items measured as individual stock keeping units (SKUs) that are managed by a vendor or supplier to the total number of stocked items held in inventory.

OBJECTIVES

The objective of this metric is to quantify the amount of maintenance, repair and operating supplies (MRO) stock that is vendor managed.

FORMULA

Vendor Managed Inventory (ratio) =
Number of Vendor Managed Stocked MRO Items / Total Number of Stocked MRO Items

This metric may also be expressed as a percentage of the value of stocked inventory.

Vendor Managed Inventory (%) =
Vendor Managed Stocked MRO Inventory Value ($) / Stocked MRO Inventory Value ($)

COMPONENT DEFINITIONS

Stocked Maintenance, Repair and Operating Materials (MRO) Inventory Value
The current book value of maintenance, repair and operating (MRO) supplies in stock, including consignment and vendor-managed inventory. Stocked MRO inventory value includes the value of MRO materials in all storage locations including satellite and/or remote storeroom locations, whether or not that material is included in inventory asset accounts or an allocated portion of pooled spares. Estimates the value of unofficial stores in the plant, even if they are not under the control of the storeroom or are not on the books. Includes estimated value for stocked material that may be in stock at zero value because of various computerized maintenance

management systems (CMMS) and/or accounting idiosyncrasies, etc. Does not include raw material, finished goods, packaging materials and related materials.

The monetary cost of an individual storeroom item is calculated as: Monetary Cost of Individual Storeroom Item = Quantity on Hand × Individual Item Cost

The aggregated cost of all storeroom items is calculated as: ∑N (Quantity on Hand × Individual Item Cost)i.

Vendor Managed Inventory
Stocked items measured as individual stock keeping units (SKUs) that are managed by a vendor or supplier.

QUALIFICATIONS

1. Time basis: Annually
2. This metric is used by storeroom, purchasing and finance personnel.
3. It provides the data to aid in the evaluation of storeroom management.
4. Vendor managed inventory is typically low value, high volume MRO materials and consumables.
5. Converting an item to vendor managed stock frees the storeroom personnel from actively managing these items, enabling them to focus on higher value added activities (e.g., ABC analysis, rationalization, cycle counting, etc.)
6. All vendor managed inventory items should be assigned a unique SKU.
7. When calculating vendor managed inventory based on value, the value of all items should be on the same cost basis (e.g., purchased costs, replacement cost, with or without shipping, etc.)
8. Since vendor managed inventory is not managed as inventory stocked items, plants may have difficulty determining the stocked value and may have to use the value from invoices as a substitute for the on-hand value.
9. Vendor managed inventory can be used for trending and benchmarking.

SAMPLE CALCULATION

A given company manages several plants, all with central storerooms for the control of their MRO. Plant A has a total of 5,013 items (measured as SKUs) in their MRO inventory. An analysis of the inventory stock records revealed that there are an additional 246 items managed by a vendor.

Number of items in the MRO inventory = 5,013 stock items (measured as SKUs)
Number of vendor managed inventory items = 246 items (measured as SKUs)
Total number of stocked items = 5,013 + 246 = 5,259

Vendor Managed Inventory (ratio) =
Number of Vendor Managed Stocked MRO Items / Total Number of Stocked MRO Items

Vendor Managed Inventory (ratio) = 246 / 5259
Vendor Managed Inventory (ratio) = 1:21 or 4.7% of stocked inventory is vendor managed

The total value of the 5,013 stocked items is $2,030,109 and the value of the 246 vendor managed items is $25,036.

Stocked MRO Inventory Value ($) = $2,030,109 + $25,036 = $2,055,145

Vendor Managed Inventory (%) =
Vendor Managed Stocked MRO Inventory Value ($) / Stocked MRO Inventory Value ($)

Vendor Managed Inventory (%) = $25,036 / $2,055,145
Vendor Managed Inventory (%) = 1.2% of the value of the stocked inventory

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee was unable to find any agreed upon target ranges, minimum/maximum values, benchmarks or references for use as target values for this metric. SMRP will update this metric as appropriate should future work help establish targets for this metric.

While no target values are currently available, SMRP encourages plants to use this metric to help manage the maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

Since this metric can be measured on an item basis (preferred) or value basis (local currency), when comparing plants make sure the basis is the same between the compared metrics.

Utilizing vendors to manage maintenance inventory does not relieve the materials management group from oversight. Vendor managed inventory should have reordering parameters established (e.g., min/max levels) and a formal vendor auditing process in place.

Vendor managed inventory should not be confused with consignment inventories which are inventories owned by the vendor and paid for by the facility when used. While vendor managed inventories are most commonly associated with low value high usage inventory items stocked at the facility, consignment inventories are commonly associated with high cost spares and critical spares which could be stocked on-site or at the vendor's storeroom.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

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WORK MANAGEMENT METRIC

5.5.33 STOCK OUTS

Published on February 1, 2010
Revised on August 12, 2015

DEFINITION

This metric is the measure of the frequency that a customer goes to the storeroom inventory system and cannot immediately obtain the part needed.

OBJECTIVES

This metric is used to maintain the appropriate balance in stocked inventory. Too much inventory increases working capital unnecessarily. Too little inventory results in unnecessary delay and equipment downtime that can negatively impact costs and profits.

FORMULA

Stock Outs (%) =
(Number of Inventory Requests with Stock Out / Total Number of Inventory Requests) × 100

This formula can also be expressed as SO (%) = NIRWSO / TNIR × 100.

COMPONENT DEFINITIONS

Number of Inventory Requests with Stock Out
An inventory request is a stock out if the requested item is normally stocked on site and the inventory request is for a normal quantity of the item, but the inventory on hand is insufficient to fill the request.

Total Number of Inventory Requests
The total of all requests for items listed as stocked in the storeroom inventory system.

QUALIFICATIONS

1. Time Basis: Monthly
2. This metric is used by maintenance, storeroom and purchasing management.
3. Integrated supply involves maintaining stock records in a storeroom inventory system, but storing items at a vendor's site. Deliveries are made on a prearranged schedule with emergency delivery available. The advantage of integrated supply is that it reduces working capital and storage requirements with minimal risk. Stock outs can be measured in an integrated supply arrangement.
4. Consignment involves keeping vendor owned inventory onsite. The vendor owns the inventory until it is consumed. The advantage of consignment is reduced work capital. Stock outs can be measured in an integrated supply arrangement.
5. This metric is best used with other indicators (e.g., SMRP Metric 5.5.31) that provide a complete picture of storeroom inventory.
6. Information gleaned from stock out reports should be analyzed to assess stocking levels based on consumption trends.
7. Stocking level thresholds should balance working capital savings with risk.

SAMPLE CALCULATION

A storeroom receives 1,234 stock requests in a given month. There were 30 requests in this same month where there was insufficient inventory to fill the request. Analyses of these 30 requests found four that were excessive orders beyond normal request quantities; therefore, these four requests did not meet the criterion for stock outs. The remaining 26 requests were stock outs.

Stock Outs (%) =
(Number of Inventory Requests with Stock Out / Total Number of Inventory Requests) × 100

Stock Outs (%) = (26 / 1234) × 100
Stock Outs (%) = 0.021 × 100
Stock Outs (%) = 2.1%

BEST-IN-CLASS TARGET VALUE

Less than (<) 2%

CAUTIONS

Stock outs are measured at the individual line items level and for total quantity requested/required versus supplied (e.g., no partial credit).

Fill rate is sometime used in place of stock out rate. The fil rate and stock out rate are equal to a 1:1 ratio.

HARMONIZATION

This metric and its supporting definitions are similar or identical to the indicator O26 in standard EN15341.

Note 1: The difference between this metric and indicator O26 in standard EN15341 is in the way the performance is calculated. EN 15341 measures the success rate, while SMRP 5.5.33 metric measures the failure rate.

Note 2: The formula for the calculation of SMRP Metric 5.5.33 based on the O26 calculation is: 100 % - (Value from EN 15341, O26) = Result for SMRP Metric 5.5.33.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the O26 indicator. Additional information is available in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

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WORK MANAGEMENT METRIC

5.5.34 INACTIVE STOCK

Published on April 16, 2009
Revised October 25, 2016

DEFINITION

This metric is the ratio of the number of inactive maintenance, repair and operating (MRO) inventory stock records to the total number of MRO inventory stock records excluding critical spares and non-stock inventory records.

OBJECTIVES

The objective of this metric is to measure the percentage of non-critical MRO supply stock with no usage for 12 or more months. A secondary objective is to use this information to calculate the potential for a reduction in working capital through changes in stocking levels (e.g., deletion, reduction in the quantity on hand, etc.).

FORMULA

Inactive Stock Records (%) =
{[Number of Inactive Inventory Stock Records – (Critical Spares Records + Non-stock Records)] / [Total Number of Inventory Stock Records – (Critical Spares Records + Non-stock Records)]} × 100

This metric can also be calculated based on the value of stocked inventory.

Inactive Stock Value (%) =
[(Inactive Inventory Stock Value - Critical Spares Value) / (Inventory Stock Value – Critical Spares Value)] × 100

COMPONENT DEFINITIONS

Critical Stock Item

An item that is inventoried because having the part on-hand is considered essential to the overall reliability of the operation due to its high cost, long lead time and/or negative impact on a plant's safety, environmental impact, operation and/or downtime should the part be needed and not be in stock. Also called critical, emergency or insurance spares.

Inactive Inventory Stock Record
An inventoried maintenance, operating and repair (MRO) storeroom item with no usage for 12 months or longer.

Inactive Inventory Stock Value
The current book value of maintenance, repair and operating supplies (MRO) in stock with no usage for 12 or more months, including consignment and vendor-managed stores. Includes the value of inactive MRO materials in all storage locations, including satellite and/or remote storeroom locations whether or not that material is included in inventory asset accounts or an allocated portion of pooled spares. Also includes estimated value for stocked material that may be in stock at zero value because of various maintenance management systems (MMS) and/or accounting idiosyncrasies, etc. Does not include raw material, finished goods, packaging materials and related materials.

Inventory Stock Record
The individual record describing the part that is inventoried, represented by a unique inventory number or stock keeping unit (SKU).

Inventory Stock Value
The current book value of MRO supplies in stock, including consignment and vendor-managed inventory. Includes the value of MRO materials in all storage locations, including satellite and/or remote storeroom locations whether or not that material is included in inventory asset accounts or an allocated portion of pooled spares. Estimates the value of "unofficial" stores in the plant even if they are not under the control of the storeroom and even if they are not "on the books". Includes estimated value for stocked material that may be in stock at zero value because of various maintenance management systems and/or accounting idiosyncrasies, etc. Does not include raw material, finished goods, packaging materials and related materials.

Non-Stock Item
An item documented in the inventory system that is not physically in the storeroom, but is documented for use on a parts list and/or for repetitive purchasing purposes. Also referred to as order on request or demand.

Stocked Maintenance, Repair and Operating Materials (MRO) Inventory Value
The current book value of maintenance, repair and operating (MRO) supplies in stock, including consignment and vendor-managed inventory. Stocked MRO inventory value includes the value

of MRO materials in all storage locations including satellite and/or remote storeroom locations, whether or not that material is included in inventory asset accounts or an allocated portion of pooled spares. Estimates the value of unofficial stores in the plant, even if they are not under the control of the storeroom or are not on the books. Includes estimated value for stocked material that may be in stock at zero value because of various computerized maintenance management systems (CMMS) and/or accounting idiosyncrasies, etc. Does not include raw material, finished goods, packaging materials and related materials.

The monetary cost of an individual storeroom item is calculated as: Monetary Cost of Individual Storeroom Item = Quantity on Hand × Individual Item Cost

The aggregated cost of all storeroom items is calculated as: ∑N (Quantity on Hand × Individual Item Cost)i.

QUALIFICATIONS

1. Time basis: Monthly and/or annually.
2. This metric is used by MRO storeroom and maintenance management to identify and quantify potential for reducing working capital.
3. An inventory item is considered inactive if the item has no usage for a specified period of time, typically 12 months or longer.
4. Items that do not have any usage over time are candidates for removal which frees up stocking space, reduces working capital and reduces storage and related costs.
5. A risk/benefit analysis should be conducted prior to removing inactive stock from inventory. Due diligence is required to ensure the inactive stock represents obsolete, dormant or excess stock and not critical stock.
6. Critical stock items are excluded from this metric.
7. Non-stock records are excluded from this metric.
8. This metric applies whether inventory items are expensed when purchased or managed as working capital (e.g., expensed when consumed).
9. The extended cost of an individual storeroom item is calculated as follows:
10. Extended Cost of Individual Storeroom Item = Quantity on Hand × Individual Item Cost

11. The aggregated cost of all storeroom items is calculated as: $\sum^{N}$ (Quantity on Hand × Individual Item Cost)$_i$.

SAMPLE CALCULATION

A given plant has 6,250 stock records, or SKU's, in inventory with a total inventory value of $4,500,000. Of the stock records, 1,250 are categorized as critical spares with a value of $2,500,000. An analysis of the inventory revealed that 1,552 stock items had no usage in the past 12 months, which includes 1,200 of the emergency/critical spares. The plant has no non-stock items identified in its inventory.

Inactive Stock Records (%) = {[Number of Inactive Inventory Stock Records - (Critical Spares Records + Non-stock Records)] /[Total Number of Inventory Stock Records – (Critical Spares Records + Non-stock Records)]} × 100

Number of Inactive Non-critical Inventory Stock Records =
Total Number of Inactive Inventory Stock Records – (Inactive Critical Stock Records + Non-stock records)

Number of Inactive Non-critical Inventory Stock Records = 1552 – 1200 = 352
Number of Non-stock Records = 0
Number of Non-critical Inventory Stock Records = 6,250 – (1250 + 0) = 5,000
Inactive Stock Records (%) = (352 × 100) / (6,250 – 1,200)
Inactive Stock Records (%) = 35,200 / 5,000
Inactive Stock Records (%) = 7.04% or 7.0%

The extended value of the 352 inactive non-critical stock items is $250,000.

Inactive Stock Value (%) = [(Inactive Inventory Stock Value - Critical Spares Value) / (Inventory Stock Value – Critical Spares Value)] × 100

Inactive Stock Value (%) = ($250,000 × 100) / ($4,500,000 - $2,500,000)
Inactive Stock Value (%) = ($25,000,000 / $2,000,000)
Inactive Stock Value (%) = 12.5%

BEST-IN-CLASS TARGET VALUE

Less than (<) 1% inactive

CAUTIONS

Since critical spares are excluded from this calculation, it is important that a consistent, unbiased and documented process is followed to define critical spares. If critical spares are not well defined, the percentage of inactive stock could be under-reported due to over reporting of critical spares which by their nature should be inactive at a highly reliable plant.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

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WORK MANAGEMENT METRIC

5.5.35 STOREROOM TRANSACTIONS

Published on April 16, 2009

DEFINITION

This metric is the ratio of the total number of storeroom transactions to the total number of storeroom clerks used to manage the inventory for a specified time period.

OBJECTIVES

The objective of this metric is to measure the workload, on a transactional basis, of the storeroom clerks for trending in order to evaluate changes in workload or for benchmarking.

FORMULA

Storeroom Transactions =
Total Number of Storeroom Transactions / Total Number of Storeroom Clerks

The number of transactions and the number of storeroom clerks must be measured for the same time period.

COMPONENT DEFINITIONS

Consignment Stock
The inventoried items that are physically stored in the storeroom, but are owned by the vendor or supplier until issued or consumed.

Direct Purchase Item
Non-inventoried items, typically purchased on an as-needed basis.

Non-Stock Item
An item documented in the inventory system that is not physically in the storeroom, but is documented for use on a parts list and/or for repetitive purchasing purposes. Also referred to as order on request or demand.

Stock Item
An inventoried item that is physically stored in the storeroom, including consignment stock, and that the storeroom manages at a specified quantity.

Storeroom Clerk
Any employee who has responsibility for the day-to-day activities in the storeroom measured as a full time equivalent (FTE). May also be known by other titles, such as storekeeper, storeroom attendant, etc. Typical duties include, but are not limited to, the following: issuing parts; stocking and labeling parts; organizing inventories; shipping equipment and materials (e.g., vendor returns, repairable spares, etc.); picking, kitting, staging, delivering and related activities; counting inventory (e.g., cycle counting); housekeeping; receiving activities (e.g., opening boxes, checking packing slips, noting discrepancies, etc.); and performing stock equipment and material maintenance activities (e.g., rotating shafts, inspecting belts, etc.).

Storeroom Transaction
Any materials management activity that results in the physical handling of an inventory item (stock or non-stock) or direct purchased item or that results in the exchange of data with the storeroom inventory management system. Inventory transactions occur any time an item is 'touched' either physically or electronically (e.g., a pick list with ten items picked would equal ten transactions). Inventory transactions include: receiving, stocking, adding, picking, kitting, staging, issuing, delivering, returning, adjusting, counting inventory stock item, EOQ analysis, etc.

QUALIFICATIONS

1. Time basis: Daily, monthly or annually
2. This metric is used by storeroom supervisors and managers.
3. This metric is used to measure the adequacy of staffing for the level of storeroom activities. It is recommended that this metric be used in conjunction with other performance measures (e.g., service, delivery, etc.).
4. This metric can also be used for benchmarking in order to make valid comparisons to other storerooms.
5. Capturing transactions is necessary to accurately use this metric.
6. Capturing transaction data may be difficult, particularly when there is no electronic history of the activity (e.g., staging, delivering).

7. This metric should not be applied to open storerooms where the storeroom clerk position is filled by multiple employees, who at various times are performing all the different responsibilities of a storeroom clerk. By definition, the storeroom clerk position is an assigned employee.

SAMPLE CALCULATION

For a given month, the storeroom recorded 7,412 total transactions. These transactions included 1,922 goods issues, 158 returns, 3,525 parts counts through cycle counting, 855 goods receipts, 870 inventory adjustments, 15 material relocations and 67 new parts inventoried. The storeroom staff consists of 2 storeroom clerks and 1 supervisor/buyer.

Storeroom Transactions =
Total Number of Storeroom Transactions / Total Number of Storeroom Clerks

Storeroom Transactions = (1,922 + 158 + 3,525 + 855 + 870 + 15 + 67) / 2
Storeroom Transactions = 7,412 / 2
Storeroom Transactions = 3,706 transactions per storeroom clerk for the month

BEST-IN-CLASS TARGET VALUE

100 to 140 per day per storeroom attendee

CAUTIONS

The best-in-class target assumes the storeroom uses barcodes and scans transactions (issuing, receiving, returning, cycle counting) where possible. Barcoding and scanning transactions (versus manually entering) can improve the storeroom's management minimizing data entry errors and can help to reduce staffing requirements while maintaining the same level of productivity.

Storeroom attendants will have additional duties that a simple analysis of storeroom transactions will not capture and which may account for variance from this target. Facilities should develop performance standards for storeroom attendants, staff storerooms consistent with these standards and evaluate workloads in terms of these standards.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

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WORK MANAGEMENT METRIC

5.5.36 STOREROOM RECORDS

Published on April 16, 2009

DEFINITION

This metric is the ratio of the number of maintenance, repair and operating (MRO) inventory stock records as individual stock keeping units (SKU's) of all MRO stock and non-stock items, including active stock, inactive stock and critical spares, to the total number of storeroom clerks used to manage the inventory.

OBJECTIVES

The objective of this metric is to measure the workload of the store clerk(s) for trending in order to evaluate changes in workload or for benchmarking.

FORMULA

Storeroom Records =
Total Number of Inventory Stock Records / Total Number of Storeroom Clerks

The number of inventory stock records and the number of storeroom clerks must be measured for the same time period.

COMPONENT DEFINITIONS

Consignment Stock
The inventoried items that are physically stored in the storeroom, but are owned by the vendor or supplier until issued or consumed.

Critical Stock Item
An item that is inventoried because having the part on-hand is considered essential to the overall reliability of the operation due to its high cost, long lead time and/or negative impact on a plant's safety, environmental impact, operation and/or downtime should the part be needed and not be in stock. Also called critical, emergency or insurance spares.

Free Issue Inventory
Low cost and high usage inventoried stock items that are available as needed without a goods issue transaction. Typically, these items are stored in a secured environment close to the point of usage. Examples of common free issue inventoried stock include nuts, bolts, gaskets, cable ties, etc.

Inactive Inventory Stock Record
An inventoried maintenance, operating and repair (MRO) storeroom item with no usage for 12 months or longer.

Inventory Stock Record
The individual record describing the part that is inventoried, represented by a unique inventory number or stock keeping unit (SKU).

Non-Stock Item
An item documented in the inventory system that is not physically in the storeroom, but is documented for use on a parts list and/or for repetitive purchasing purposes. Also referred to as order on request or demand.

Stock Item
An inventoried item that is physically stored in the storeroom, including consignment stock, and that the storeroom manages at a specified quantity.

Storeroom Clerk
Any employee who has responsibility for the day-to-day activities in the storeroom measured as a full time equivalent (FTE). May also be known by other titles, such as storekeeper, storeroom attendant, etc. Typical duties include, but are not limited to, the following: issuing parts; stocking and labeling parts; organizing inventories; shipping equipment and materials (e.g., vendor returns, repairable spares, etc.); picking, kitting, staging, delivering and related activities; counting inventory (e.g., cycle counting); housekeeping; receiving activities (e.g., opening boxes, checking packing slips, noting discrepancies, etc.); and performing stock equipment and material maintenance activities (e.g., rotating shafts, inspecting belts, etc.).

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QUALIFICATIONS

1. Time basis: Monthly and annually
2. This metric is used by storeroom supervisors and managers to assess the workload of storeroom clerks and/or for benchmarking.
3. An inventoried item is considered active if the item has been issued during the previous 12 months.
4. Include inactive stock and critical spares in this calculation since these items must be managed while in storage regardless of their usage.
5. Free issue inventory is excluded from this metric unless the free issue items are cataloged and actively managed by storeroom personnel.
6. The inventory stock record should not be confused with the quantity on hand or in stock.

SAMPLE CALCULATION

A given storeroom has 6,250 stock records (SKUs) in inventory. An analysis of the inventory stock records revealed that 1,552 stock items had no usage in the past 12 months and there are 1,250 critical spares included in the total number of stock records. The storeroom staff consists of two storeroom clerks and one supervisor/buyer.

Storeroom Records =
Total Number of Inventory Stock Records / Total Number of Storeroom Clerks

Storeroom Records = 6,250 / 2
Storeroom Records = 3,125 inventory stock records per storeroom clerk

BEST-IN-CLASS TARGET VALUE

5,000 per storeroom attendant

CAUTIONS

Storeroom productivity as measured by storeroom records per storeroom attendant can be affected both by the storeroom’s organization and the use of technology.

The majority of the work in the storeroom is dependent on the number of items that are moving, the active items, as well as, the procurement cycle which by itself can create a high work load. These two items should also be known when comparing plants to one another and against this target.

In addition, barcoding and scanning transactions (versus manually entering) will improve the storeroom's management minimizing data entry errors and can help to reduce staffing requirements while maintaining the same level of productivity.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Approved by consensus of SMRP Best Practice Committee, May 30, 2012.

WORK MANAGEMENT METRIC

5.5.38 MAINTENANCE MATERIAL COST

Published on June 6, 2010
Revised on June 30, 2012

DEFINITION

This metric is the total cost incurred for materials, supplies and consumables needed to repair and maintain plant and facility assets for a specified time period, expressed as a percentage of the total maintenance cost for the period.

OBJECTIVES

The objective of this metric is to monitor the contribution of maintenance material costs to total maintenance costs. This value can then be compared to industry benchmarks and analyzed for cost reduction opportunities.

FORMULA

Maintenance Material Cost Percentage (%) =
[Maintenance Material Cost ($) / Total Maintenance Cost ($)] × 100

COMPONENT DEFINITIONS

Maintenance Material Cost
The cost of all maintenance, repair and operating material (MRO) used during the specified time period. Includes stocked MRO inventory usage, outside purchased materials, supplies, consumables and the costs to repair spare components. Also includes materials used for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include material used for capital expenditures for plant expansions or improvements.

Total Maintenance Cost
The total expenditures for maintenance labor, including maintenance performed by operators such as total productive maintenance (TPM), materials, contractors, services and resources. Includes all maintenance expenses for outages, shutdowns or turnarounds, as well as normal

operating times. Also includes capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include capital expenditures for plant expansions or improvements.

QUALIFICATIONS

1. Time basis: Monthly, quarterly and/or annually
2. This metric is used by corporate managers and executives, as well as plant managers, maintenance managers and human resources managers to compare different sites.
3. This metric is useful for developing trends in the distribution of maintenance spending.
4. This metric is also useful to compare to maintenance labor cost in order to get an idea of potential improvement areas. A high percentage of material cost to labor cost may indicate an ineffective preventive maintenance (PM)/predictive maintenance (PdM). program, while a high percentage of labor cost may indicate a lack of effective planning.
5. This metric is useful for comparing the organization's performance relative to industry benchmarks.

SAMPLE CALCULATION

For a given plant, maintenance costs for the year were as follows:

Internal Maintenance Labor	$8,144,000
Maintenance Staff Overhead (supervisors, planners, etc.)	$2,320,000
Contractor labor	$1,125,000
Annual Equipment Maintenance Contracts	$ 96,000
Janitorial Service Contracts	$ 380,000
Maintenance Materials	$9,992,000
Total Maintenance Cost	**$22,057,000**

Maintenance Material Cost Percentage (%) =
[Maintenance Material Cost ($) / Total Maintenance Cost ($)] ×100

Maintenance Material Cost Percentage (%) = ($9,992,000 / $22,057,000) × 100
Maintenance Material Cost Percentage (%) = 0.453 ×100
Maintenance Material Cost Percentage (%) = 45.3%

BEST-IN-CLASS TARGET VALUE

50%

CAUTIONS

This target value is valid for prevailing labor rates in the United States and Canada. Lower labor rates in other parts of the world may drive this percentage significantly higher.

HARMONIZATION

This metric and its supporting definitions are similar to EN 15341 Indicator E11.

Note 1: The difference between this metric and indicator E11 in EN15341 is that EN 15341 has a broader definition and includes depreciation of maintenance owned equipment and facilities in total maintenance cost (office, workshop and warehouse).

Note 2: It is assumed that operating materials ("O" component in MRO) is only for maintenance purposes.

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the E11 indicator.

Additional information is provided in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

REFERENCES

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WORK MANAGEMENT METRIC

5.5.71 CONTRACTOR COST

Published on April 16, 2009

DEFINITION

This metric is the percentage of contractor costs of the total maintenance costs used to maintain assets.

OBJECTIVES

The objective of this metric is to quantify contractor costs for trending, comparison and benchmarking.

FORMULA

Contractor Maintenance Cost Percentage =
[Contractor Maintenance Cost ($) / Total Maintenance Cost ($)] × 100

COMPONENT DEFINITIONS

Contractor Maintenance Cost

The total expenditures for contractors engaged in maintenance on site. Includes all contractor maintenance labor and materials costs for normal operating times, as well as outages, shutdowns or turnarounds. It also includes contractors used for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include contractors used for capital expenditures for plant expansions or improvements.

Total Maintenance Cost

The total expenditures for maintenance labor, including maintenance performed by operators such as total productive maintenance (TPM), materials, contractors, services and resources. Includes all maintenance expenses for outages, shutdowns or turnarounds, as well as normal operating times. Also includes capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include capital expenditures for plant expansions or improvements.

QUALIFICATIONS

1. Time basis: Monthly and annually
2. This metric is used by corporate managers and executives, plant managers, maintenance managers and human resources managers to measure and compare contractor costs.
3. Do not rely on this metric alone for contractor cost evaluation (e.g., the labor portions may have to be considered separately).
4. This metric can be used as an aid to determine if the permanent maintenance workforce is appropriately sized and staffed for the maintenance workload.
5. Top performers typically use some complement of contractors for specialty crafts and/or skills, for peak or abnormal workloads, such as outages, turnarounds or shutdowns and for specialty tools or resources (e.g., cranes, vibration measurements, etc.).

SAMPLE CALCULATION

For a given plant, annual Contractor Maintenance Cost is $2,600,000 and the annual total maintenance cost is $10,000,000.

Contractor Maintenance Cost Percentage =
[Contractor Maintenance Cost ($) / Total Maintenance Cost ($)] × 100

Contractor Maintenance Cost Percentage = [$2,600,000 / $10,000,000] × 100
Contractor Maintenance Cost Percentage = 0.26 × 100
Contractor Maintenance Cost Percentage = 26.0%

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee was unable to find any target ranges, minimum/maximum values, benchmarks or other references for target values for this metric. SMRP will update this metric as appropriate should future work help establish targets for this metric.

While no target values are currently available, SMRP encourages plants to use this metric to help manage the maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric and its supporting definitions are similar or identical to the indicator E10 in standard EN15341.

Note 1: The difference between this metric and indicator E10 in standard EN15341 is that EN 15341 has a broader definition and includes depreciation of maintenance owned equipment and facilities in total maintenance cost (office, workshop and warehouse).

This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the E10 indicator.

Additional information is available in the document *Global Maintenance and Reliability Indicators* available for purchase as a publication in the SMRP Library.

REFERENCES

Approved by consensus of SMRP Best Practice Committee.

WORK MANAGEMENT METRIC

5.5.72 CONTRACTOR HOURS

Published on October 3, 2009
Revised on August 12, 2015

DEFINITION

This metric is the percentage of contractor labor hours out of the total maintenance labor hours used to maintain assets.

OBJECTIVES

The objective of this metric is to quantify contractor labor hours for trending, comparison and benchmarking.

FORMULA

Contractor Hours Percentage = (Contractor Labor Hours / Total Maintenance Labor Hours) × 100

This formula can also be expressed as CH (%) = CLH / TMLH) × 100.

COMPONENT DEFINITIONS

Contractor Labor Hours

The hours used by contractors performing maintenance on the site. This includes all hours for routine service work, as well as those used on outages, shutdowns or turnarounds. Includes contractor hours used for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include contractor hours used for capital expenditures for plant expansions or improvements.

Total Maintenance Labor Hours

Expressed in hours and includes all maintenance labor hours for normal operating times as well as outages, shutdowns and turnarounds. If operator hours spent on maintenance activities are captured, they should be included in the numerator and denominator of all applicable metrics. Include labor hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include labor hours used for capital expansions or improvements. Typically, total maintenance labor hours do not include temporary contractor labor hours.

QUALIFICATIONS

1. Time basis: Monthly and yearly.
2. This metric is used by corporate managers and executives, plant managers, maintenance managers and human resources managers to measure and compare contractor hours.
3. It is useful for developing trends in overall labor usage to determine whether the permanent maintenance workforce is appropriately sized and staffed for the maintenance workload.
4. Top performers typically use some complement of contractors for specialty crafts and/or skills, for peak or abnormal workloads (such as outages/turnarounds/shutdowns) and for the use of specialty tools/resources (e.g., cranes, vibration measurements, etc.).

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SAMPLE CALCULATION

For a given plant, the maintenance labor used in a month at the site is:

Maintenance craft labor	821 hours
Contractors used for roofing repairs	240 hours
Chiller compressor service contract labor	13 hours
Contractor used to clean the cooling tower basin	200 hours
Contract thermographic scan	16 hours
Total maintenance labor hours used	**1290 hours**

Contractors used for roofing repairs	240 hours
Chiller compressor service contract labor	13 hours
Contractor used to clean the cooling tower basin	200 hours
Contract thermographic scan	16 hours
Contractor labor hours used	**469 hours**

Contractor Hours Percentage =
(Contractor Labor Hours / Total Maintenance Labor Hours) × 100

Contractor Hours Percentage = (469 Hours / 1290 Hours) × 100

Contractor Hours Percentage = 0.364 × 100

Contractor Hours Percentage = 36.4%

BEST-IN-CLASS TARGET VALUE

SMRP's Best Practices Committee research indicates that best-in-class values for this metric are highly variable by industry vertical and type of facility. SMRP recommends that organizations become involved in trade associations within their industry vertical, as these groups often publish such data about their industry. SMRP also encourages plants to use this metric to help manage the maintenance management process. Combined with information from other metrics and by tracking and trending this metric, plants will gain good information to help make improvements to plant maintenance and reliability programs.

CAUTIONS

There are no cautions identified at this time.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

Approved by consensus of SMRP Best Practice Committee.

WORK MANAGEMENT METRIC

5.6.1 WRENCH TIME

Published on October 3, 2009
Revised on August 12, 2015

DEFINITION

This metric is a measure of the time a maintenance craft worker spends applying physical effort or troubleshooting in the accomplishment of assigned work. The result is expressed as a percentage of total work time. Wrench time is measured through a process called work sampling.

OBJECTIVES

The objective of this metric is to identify opportunities to increase productivity by qualifying and quantifying the activities of maintenance craft workers.

FORMULA

Wrench Time Percentage = (Wrench Time Observations / Total Observations) x 100
Wrench Time Percentage = [Wrench Time (hours) / Total Hours (hours)] x 100

COMPONENT DEFINITIONS

Administrative Meetings
Scheduled and unscheduled meetings, including safety meetings, information meetings and department meetings.

Break Time
Time for scheduled and unscheduled breaks.

Contributing Time
The time that is directly related to accomplishing the assigned work including field level risk assessments, instruction time, loaded travel (transporting materials or tools) site cleanup, returning equipment to service and shift hand-over. This time is required to complete the work however is not included in the wrench time calculation.

Instruction Time
The time when a maintenance craft worker is receiving work instruction (e.g., assignment of jobs at the beginning of a shift).

Meeting Time
Scheduled and unscheduled meetings including safety meetings, information meetings, department meetings and other similar meetings.

Non-Contributing Time
The time not directly related to accomplishing the assigned work (e.g., breaks, personal time, signoff and wash-up, administrative meetings, unloaded travel (not carrying materials or tools), planning, waiting, and training).

Non-Productive Work Time
The time not directly related to accomplishing the assigned work (e.g., breaks, personal time, meetings, travel, planning, instruction, waiting, procuring tools and materials and training).

Personal Time
The time when a worker is taking care of personal business (e.g., making or receiving a personal phone call, meeting with Human Resources or a union steward, using the restroom and other similar personal activities).

Planning Time
The time when a maintenance craft worker is planning a job. Includes planning emergency and unscheduled work, including scope creep.

Total Work Time
The total time that maintenance craft workers are being paid to accomplish work, commonly referred to as being "on the clock." This includes straight time and overtime, whether scheduled or unscheduled.

Training Time
The time when a maintenance craft worker is receiving formal or informal training. Can be in a classroom or on the job.

Unloaded Travel Time
The time when a maintenance craft worker is traveling, regardless of the reason or the mode of transportation (e.g., not carrying materials or tools while walking, riding, etc.)

Waiting Time
The time when a maintenance craft worker is waiting, regardless of the reason.

Wrench Time
The time when a maintenance craft worker is applying physical effort or troubleshooting in the accomplishment of assigned work.

Work Sampling
The process of making a statistically valid number of observations to determine the percentage of total work time workers spend on each activity.

QUALIFICATIONS

1. Time basis: Triggered by site review of performance indicators
2. This metric is used by maintenance managers and supervisors:
    a. To enable comparison to prior studies for trending purposes.
    b. To enable comparison to other maintenance operations.
    c. To identify inefficiencies inherent in lunch room, tool cribs, storage locations or delivery processes.
    d. To identify opportunities for improvement in planning and scheduling.
    e. To identify barriers to productivity in the maintenance work process.
    f. To justify changes in the maintenance work force based on productivity.
3. This metric is used by management:
    a. To verify the value for paid maintenance services.
    b. To identify Operations opportunities to improve maintenance wrench time. For example:
        i. Safe work permitting
        ii. Equipment preparation, including decontamination and log out/tag out
        iii. Schedule changes or interruptions
4. This metric can be used for measuring a specific crew, a specific craft or for all maintenance craft workers in a unit or plant.

5. It is recommended that work sampling not be used to measure the activities of an individual worker. If used in this way, workers will likely deviate from their normal behaviors whenever being observed.
6. It is recommended that different crafts and/or crews be measured separately since the barriers to productivity may vary by craft or crew.
7. It is recommended that observations be taken throughout the total work time of the craft workers being measured to determine the time relevance associated with any activity (e.g., clean-up at the end of a shift).
8. To avoid bias, it is strongly recommended that observations be made by an impartial party.
9. A statistically valid number of observations must be made. A snapshot in time may not be representative of the norm.
10. This metric does not address the quality of work.
11. Use time category definitions that are appropriate for the work performed at the plant where worker productivity is being measured.
12. Breaking waiting time into subcategories can be helpful in identifying improvement opportunities. Maintenance craft workers typically wait for instruction, equipment decontamination and safety support, such as work permits or lock out/tag out, materials, tools, coworkers, etc.
13. Breaking travel time into subcategories can help identify improvement opportunities. Maintenance craft workers typically travel for tools, materials, instruction, to break facilities, etc.
14. The focus should be on identifying and quantifying non-contributory activities.
15. Analysis, including root cause analysis (RCA), may be beneficial or necessary to understand the causes of non-contributory activities.
16. The percentage of any given activity can be multiplied by the total work time in order to estimate the total amount of time spent on any given activity.
17. The total cost or value of any activity can be calculated by multiplying the fully loaded craft cost by the number of workers by the number of hours spent on the activity.

SAMPLE CALCULATION

An assessment was conducted on a 10-person maintenance crew for one 8-hour shift.

Total Work Time = 10 workers x 8 hours = 80 hours

There are three formal break times: 15-minute paid break at mid-morning, 30-minute unpaid lunch and 15-minute paid break at mid-afternoon.

There is a startup meeting used to assign work (instruction) at the beginning of the shift that typically lasts 20 minutes and a 10-minute transition (planning) meeting at the end of the shift. There was a 30-minute safety meeting after lunch.

Observation

Type	Break	Personal	Meeting	Travel	Planning	Instruct	Wait	Train	Wrench	Total
# of Observations	14	7	15	27	10	10	15	0	49	147
Percentage	9.5%	4.8%	10.2%	18.4%	6.8%	6.8%	10.2%	0%	33.3%	100 %
Hours	7.6hr	3.8hr	8.2hr	14.7hr	5.4hr	5.4hr	8.2hr	0hr	26.7hr	80hr

Wrench Time Percentage= (Wrench Time / Total Work Time) × 100

Wrench Time Percentage = (26.7 hours / 80 hours) × 100
Wrench Time = 0.33 × 100
Wrench Time = 33%

BEST-IN-CLASS TARGET VALUE

50% to 55%

CAUTIONS

This target value is typically not achievable without a robust and mature planning practice and a highly proactive maintenance environment, where most planned work was identified as being necessary long before the actual repair is executed. Extensive use of predictive technologies for early work identification is typically necessary to provide planners with enough of a backlog of plannable work to result in a large percentage of executed work having been well-planned in advance. Typical wrench time in a reactive maintenance environment without effective planning is less than 30%.

HARMONIZATION

This metric has not been harmonized with European standard EN 15341: Maintenance Indicators.

REFERENCES

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WORK MANAGEMENT METRIC

5.7.1 CONTINUOUS IMPROVEMENT HOURS

Published on January 28, 2010
Revised on August 1, 2012

DEFINITION

This metric is the percentage of labor hours of maintenance employees used on continuous improvement activities.

OBJECTIVES

The objective of this metric is to quantify the maintenance labor hours used on continuous improvement activities. This metric is also used to trend the resource investment in continuous improvement activities.

FORMULA

Continuous Improvement Hours (%) =
(Maintenance Labor Hours Used for Continuous Improvement / Total Maintenance Employee Hours) x 100

COMPONENT DEFINITIONS

Maintenance Employees
All personnel, salaried and hourly, direct and indirect, who are responsible for executing work assignments pertaining to the maintenance of physical assets and components. Same as internal maintenance employees.

Maintenance Labor Hours Used for Continuous Improvement
Used for continuous improvement are the total direct and indirect maintenance labor hours used on continuous improvement activities. Examples of continuous improvement activities are: lean, six sigma, work process redesign, work practice redesign, work sampling and other similar performance improvement activities. Examples of areas that could be improved include: availability, reliability, maintainability, quality, productivity, safety, environment and costs. Do not include labor hours for capital expenditures for plant expansions or improvements.

Total Maintenance Employee Hours
All internal maintenance labor hours, both straight time and overtime. Internal maintenance personnel are plant employees only, not contractors. Includes hours for normal operating times, as well as outages, shutdowns or turnarounds. Includes hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Include the hours for staff overhead support (supervisors, planners, managers, storeroom personnel, etc.). Include the hours for maintenance work done by operators. Does not include hours used for capital expenditures for plant expansions or improvements.

QUALIFICATIONS

1. Time basis: Monthly and annually
2. This metric is used by site, maintenance and continuous improvement management to measure and track the resource investment in maintenance improvement.
3. This metric provides the best data when used to measure and track the resource investment in maintenance improvement.
4. Some organizations prefer to track continuous improvement hours used rather than the percentage; however, setting the standard calculation as a percentage normalizes the data and enables comparison between plants of varying sizes.
5. Continuous improvement is a broader term than improvement. Improvement may be limited to a single improvement event, whereas continuous improvement activities are ongoing efforts that provide benefits to a company’s products, service and processes.

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SAMPLE CALCULATION

A given plant invested the following maintenance resources in a given month to improve performance. Total Maintenance Employee Hours worked during the month were 8,083.

- Mechanics and supervisor hours used for a safety fish bone analysis: 12 hours
- Electrician hours used on a task force to improve the quality on a production line: 28 hours
- Reliability engineer hours used to extend the mean time between failures (MTBF) on a critical piece of equipment: 24 hours
- Maintenance supervisor hours used on a production debottlenecking project: 6 hours
- Maintenance trainer hours used to instruct on an improved alignment method: 9 hours
- Maintenance planner hours used on a lean six sigma (LSS) project to improve planning accuracy: 11 hours
- Maintenance administrative hours used to improve time keeping accuracy: 4 hours
- Maintenance manager hours used to analyze work sampling results (to eliminate
- barriers): 3 hours

Continuous Improvement Hours (%) = (Maintenance Labor Hours Used for Continuous Improvement / Total Maintenance Employee Hours) x 100

Continuous Improvement Hours (%) = [(12 + 28 + 24 + 6 + 9 + 11 + 4 + 3) / 8,083] × 100
Continuous improvement hours (%) = (97 / 8,083) × 100
Continuous improvement hours (%) = 0.012 × 100 = 1.2%

BEST-IN-CLASS TARGET VALUE

Greater than (>) 5%

HARMONIZATION

This metric and its supporting definitions are similar or identical to the indicator O8 in standard EN15341. This document is recommended by the European Federation of National Maintenance Societies (EFNMS) as a guideline for calculating the O8 indicator.

REFERENCES

None

Guidelines

MAINTENANCE & RELIABILITY BODY OF KNOWLEDGE

SMRP
Society for Maintenance & Reliability Professionals

SMRP GUIDELINE 1.0

1.0 DETERMINING REPLACEMENT ASSET VALUE (RAV)

Published on April 16, 2009

Guidelines provide additional information or further clarification of component terms used in SMRP Best Practice Metrics. This guideline is for Replacement Asset Value (RAV).

DEFINITION

Also referred to as estimated replacement value (ERV), replacement asset value (RAV) is the dollar value that would be required to replace the production capability of the present assets in the plant. Includes production/process equipment as well as utilities, facilities and related assets. Also includes the replacement value of buildings and grounds if these assets are included in maintenance expenditures. Does not include the insured value or depreciated value of the assets, nor does it include the value of real estate, only improvements.

PURPOSE

RAV is used as the denominator in a number of calculations to normalize cost performance of facilities of various sizes within a given industry. These calculations are used to determine the performance of the maintenance and reliability function relative to other facilities in the same or similar industry.

INCLUSIONS

- Building envelope
- All physical assets (equipment) that must be maintained on an ongoing basis
- The value of improvements to grounds (provided these must be maintained on an ongoing basis)
- Capitalized engineering costs

EXCLUSIONS

- Value of land on which the facility is situated
- The value of working capital:
    - Raw material inventory
    - Work-in-process inventory
    - Finished goods inventory
    - Spare parts inventory
- Capitalized interest
- Pre-operational expense
- Investments included in construction of the facility that are not part of the facility assets
- Mine development

CALCULATION METHODS

There are four methods generally used to determine the RAV of a facility. These methods, described below, are ranked in order of decreasing accuracy.

1. Determine the original capital cost for the facility and equipment. Adjust for inflation since the date of commissioning. Different indexes are available, such as inflation data from the US Bureau of Labor Statistics at www.bls.gov , Chemical Engineering's Plant Cost Index (CECPI) at http://www.che.com). Add the value of any significant capital expansions (not replacements) that have occurred since commissioning, also adjusted for inflation. Subtract the value of any decommissioned or abandoned assets, also adjusted for inflation.
2. Use the insured asset value (IAV) provided by the insurance company. If using this method, it should be recognized that the IAV may be less accurate than the RAV (as determined above), depending on the level of risk the organization decides to assume. However, this inaccuracy normally does not significantly impact the calculations in which RAV is used.
3. If the facility was recently part of a corporate acquisition, the purchasing company may have contracted an independent professional appraiser to determine the replacement

value. The appraised value normally includes items such as working capital and land values, so adjustments should be made as appropriate.

4. If the organization has facilities of similar size, age and capacity, RAV calculations made at one facility can be extended to other facilities and adjusted appropriately. It should be recognized that this is usually the least accurate method for determining RAV.

APPLICABLE METRICS

- 1.1 Ratio of Replacement Asset Value (RAV) to Craft-Wage Headcount
- 1.4 Stocked MRO Inventory as a Percentage of Replacement Asset Value (RAV)
- 1.5 Total Maintenance Cost as a Percentage of Replacement Asset Value (RAV)

REFERENCES

Approved by consensus of SMRP Best Practice Committee.

SMRP GUIDELINE 2.0

2.0 UNDERSTANDING OVERALL EQUIPMENT EFFECTIVENESS (OEE)

Published April 16, 2009

Guidelines provide additional information or further clarification of component terms used in SMRP Best Practice Metrics. This guideline is for overall equipment effectiveness (OEE). This guideline is not intended to be a thorough review of OEE, but rather an explanation of how OEE is defined as a SMRP best practice metric.

DEFINITION

Overall equipment effectiveness (OEE) is a metric is a measure of equipment or asset performance based on actual availability, performance efficiency and quality of product or output when the asset is scheduled to operate. OEE is typically expressed as a percentage. The process can be a single piece of equipment, a manufacturing cell, a production line or a plant.

OEE takes into account equipment availability, how efficiently the equipment performs and the quality of the products produced.

OEE = Availability × Performance Efficiency × Quality

PURPOSE

The purpose of OEE is to identify sources of waste and inefficiencies or process losses that reduce availability (downtime), performance efficiency (rate/speed) and quality (defects) so that corrective action can be taken to improve the process.

OEE COMPONENTS

Figure 1 on the next page is provided as an aid to help understand the various components used to calculate OEE.

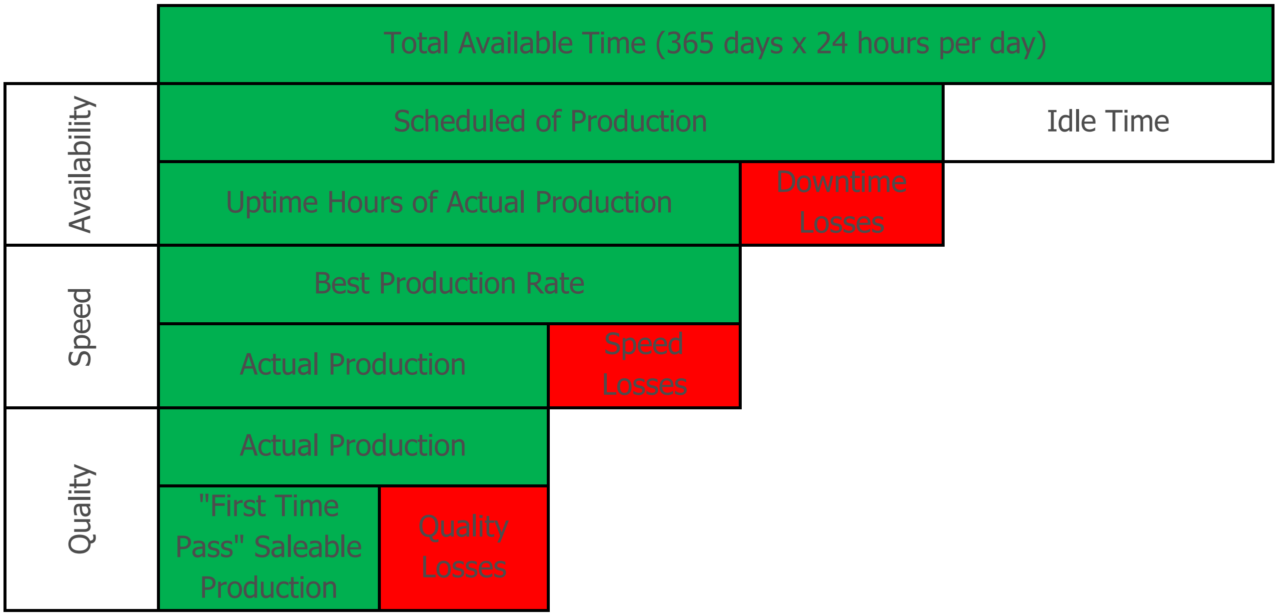

Figure 1. OEE Components

AVAILABILITY

Availability is defined as the percentage of the time that the asset is actually operating (uptime) compared to when it is scheduled to operate. It is also called operational availability. It is calculated as follows:

Availability (%) = {Uptime (hrs) / [Total Available Time (hrs) – Idle Time (hrs)]} × 100

Scheduled Hours

Production can occur every day of the year. Total available time in Figure 1 above is calculated as 365 days per year, 24 hours per day, seven days per week. Equipment, however, may not be scheduled to operate at all times due to business conditions (no demand, seasonal weather conditions, holidays, test runs, etc.) which are beyond the control of the plant.

Scheduled hours are calculated by deducting these non-scheduled operating hours or idle time (defined as the amount of time an asset is idle or waiting to run). It is the sum of the times when there is no demand, feedstock or raw material and other administrative idle time (e.g., not scheduled for production) from the total available time. This is done so that the plant is not penalized by conditions which it cannot control; however, if planned/scheduled maintenance is performed during time not scheduled for business reasons, these planned/scheduled maintenance hours should be included in the scheduled hours.

Uptime Hours

Uptime hours are calculated by determining the total duration of the downtime events that stopped scheduled production and subtracting this from the calculated scheduled hours. Typical sources of downtime losses include equipment failures, changeover/set-up time, planned/scheduled maintenance, operator shortages and related conditions.

Performance Efficiency (Rate/Speed)

Performance efficiency (rate/speed) is the degree to which the equipment operates at historical best speeds, rates and/or cycle times. It is calculated by either of the methods below.

Performance Efficiency (rate/speed) (%) = (Actual Run Rate / Best Run Rate) × 100
Performance Efficiency (rate/speed) (%) = (Best Cycle Time / Actual Cycle Time) × 100

Run rate is expressed in units produced per operating time, and cycle time is expressed as time per unit of output. The performance efficiency (rate/speed) calculation considers all units produced and includes good and defective product.

The ideal run rate and ideal cycle time should be based on the equipment, cell, production line or plant capacity as designed and represents the maximum production rate at which the equipment can consistently and reliably operate.

The best run rate and best cycle time should be based on the equipment, cell, production line or plant capacity as designed or the historic best rate (whichever is higher) and represents the maximum production rate at which the equipment can consistently and reliably operate.

The differences between the best and actual run rates or cycle times are losses due to the performance efficiency (rate/speed) of operation. These take into account all instances when the equipment, cell, production line or plant is not operating at its best performance efficiency (rate/speed), (e.g., reduced speeds), as well as idling and minor stoppages not included in the availability delays.

The performance efficiency (rate/speed) value cannot exceed 100% to ensure that if the best performance efficiency (rate/speed) is incorrectly specified, the impact on the OEE will be minimized.

Quality
Quality is defined as the percentage of "first pass, first time" saleable production to the actual production and can be calculated by either of the methods below:

Quality (%) = ("First Pass, First Time" Saleable Production / Actual Production) × 100
Quality (%) = (Good Pieces / Total Pieces) × 100

"First Pass, First Time" Saleable Production is all production that meets all customer (or internal customer) quality specifications on the first attempt, without the need for reprocessing or rework.

Actual production is the total quantity of production produced in the given time period, regardless of its quality.

Quality losses include losses due to the product not meeting all specified quality standards, as well as scrapped product and product requiring rework. Product that must be reworked is included as a loss because the goal is zero defects by making the product right the first time.

INTERPRETATION OF OEE

The OEE metric is open to various interpretations. When comparing and benchmarking OEE, it is important that the basis for each component is fully understood and calculated the same way. Availability is the most subjective component. The hours used or excluded for availability can have a significant effect on the value of the availability component.

A literature review and discussions with experts indicate that some definitions of OEE use total time to calculate availability. In addition, some availability calculations excluded planned maintenance downtime from the scheduled hours of production. In this guideline for OEE, SMRP has placed value on what is controllable at the plant level and only includes these controllable production times.

Equally important is the comparison of the various OEE components. The classic example in literature is improving OEE through higher availability or increased performance efficiency (rate/speed), but at the expense of quality. OEE must be evaluated in the context of the entire operation with other metrics and plant comment. OEE must be part of the plant's overall improvement process.

Lastly, OEE does not provide information on the cost benefits of maximizing the OEE components. OEE is a starting point for understanding sources of plant losses and the beginning the improvement process.

OTHER METRICS

The following SMRP metrics are similar in scope:

1. 2.5 Utilization Rate
2. 2.1.2 Total Effective Equipment Performance (TEEP)

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SMRP GUIDELINE 3.0

3.0 DETERMINING LEADING AND LAGGING INDICATORS

Published on April 16, 2009

Guidelines provide additional information or further clarification of component terms used in SMRP Best Practice Metrics. This guideline is used as an aid for determining whether an indicator is leading or lagging. This guideline is not intended to be a thorough prescription, but rather an explanation of how to determine, define and use leading and lagging indicators from a SMRP Best Practice Metrics standpoint.

DEFINITION

Lagging Indicator

An indicator that measures performance after the business or process result starts to follow a particular pattern or trend. Lagging indicators confirm long-term trends, but do not predict them.

Leading Indicator

An indicator that measures performance before the business or process result starts to follow a particular pattern or trend. Leading indicators can sometimes be used to predict changes and trends.

PURPOSE

The purpose of leading and lagging indicators is to measure the performance of the maintenance and reliability process. Leading and lagging indicators provide information so that positive trends can be reinforced and unfavorable trends can be corrected.

DISCUSSION OF LEADING AND LAGGING INDICATORS

The purpose of running a business is to create shareholder value by providing a distinct product or service. Creating value starts with the needs of the customer and continues through producing a quality product and delivering it on time at a competitive price. The maintenance function is a key stakeholder in this value stream; however, maintenance as a function cannot achieve this alone.

The maintenance and reliability process represents the collection of all stakeholder tasks required to support the manufacturing or service function. The output of a healthy maintenance and reliability process is optimal asset reliability at optimal cost, which contributes to maximum shareholder value. The maintenance and reliability process is a supply chain. If a step in the process is skipped or performed at a substandard level, the process fails to maximize its contribution.

There are three sets of measurable components that make up the maintenance and reliability process.

1. Management processes and behaviors (mission and vision, people skills)
2. Operational execution (operations, design and maintenance)
3. Manufacturing performance (availability, quality, cost and benefits)

Each component is a process on its own which can be measured using both leading and lagging indicators. These indicators are used to determine the quality of each process. In this context, the components of the maintenance and reliability process can be both leading and lagging indicators, depending on where in the process the indicators are used. There is a cause and effect relationship between leading and lagging; the action being measured will cause a resulting action or effect which is also being measured. This means that a given measure could be both a lagging measure for a previous cause in the chain and a leading measure for a following effect. There are a series of causes and effects in the chain until the final lagging measures are reached.

Figure 1 illustrates the concept of an indicator being both leading and lagging, depending on the application of the metric. Preventive maintenance (PM) compliance is used to measure how much PM work was completed as scheduled. In this case, it is a lagging indicator or result of how much PM work is completed when viewed in the context of work execution. When viewed as an indicator of equipment reliability, however, PM compliance is a leading indicator of the reliability process. The higher an organization’s PM compliance, the more likely this will lead to improved equipment reliability. Similarly, improved equipment reliability will lead to reduced maintenance cost, which is a lagging indicator of the overall maintenance process.

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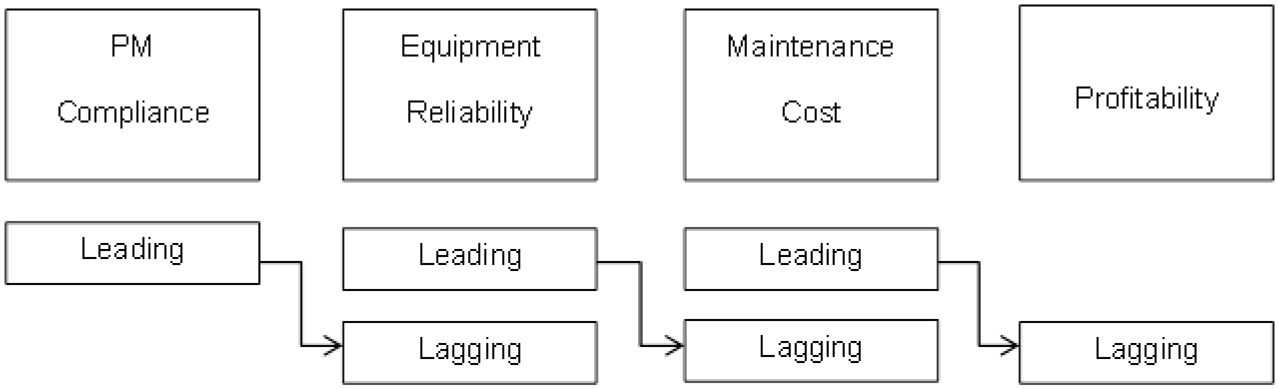

Figure 1. Leading and Lagging Indicator Mapping

When considering a leading measure, it is beneficial to express it in terms of what it is a leading measure for (e.g., What is the lagging measure that will be affected?)

Figure 2 depicts the relationship between the different maintenance and reliability processes components, their alignment with the SMRP Body of Knowledge (BoK) and the concept of leading and lagging indicators. The final result of a behavior and process component is a lagging indicator; however, it can be a leading indicator for the operational execution component. In this context, the lagging indicators of one component can also be viewed as the leading indicators of another dependent component.

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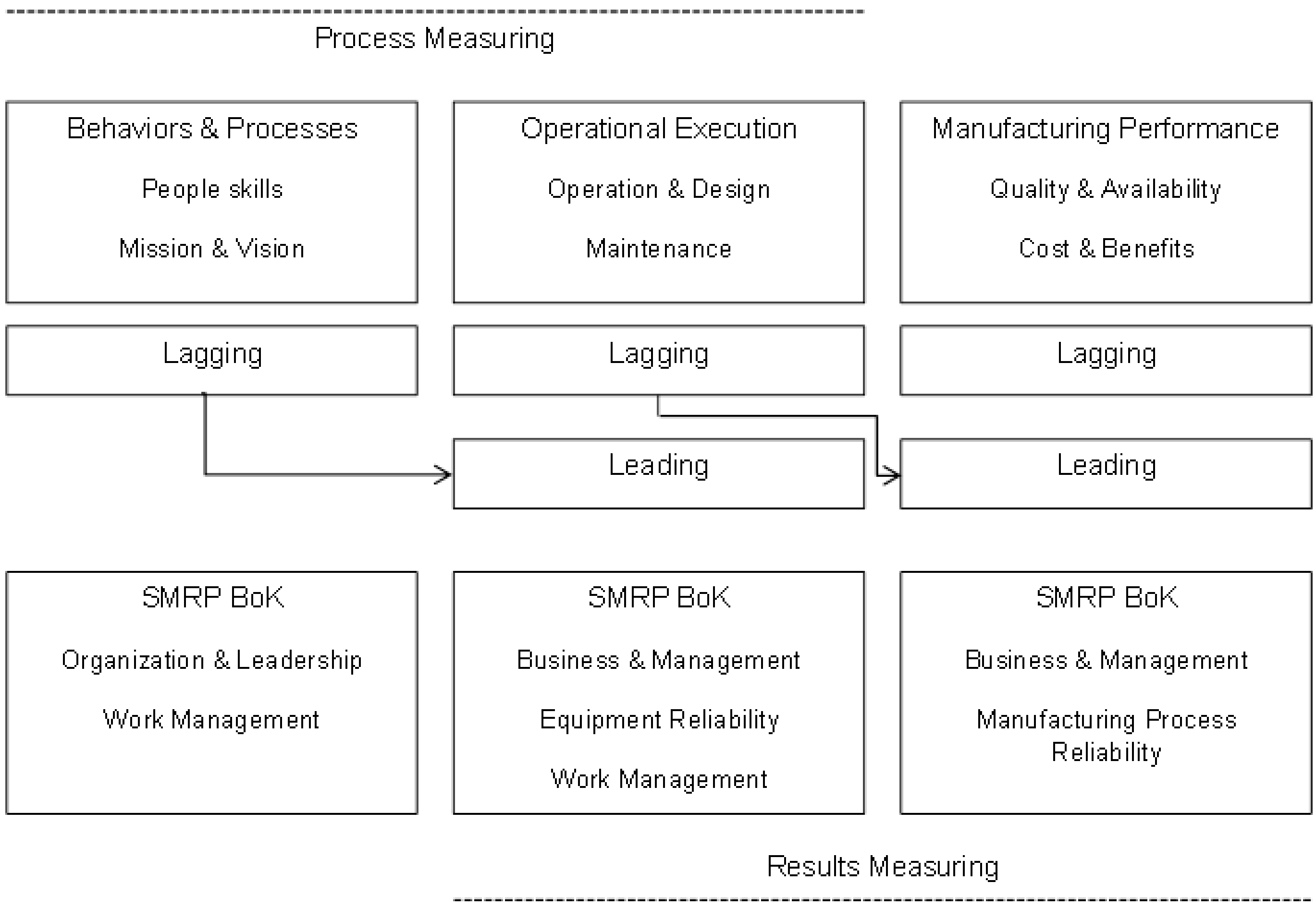

Figure 2. Components of the Maintenance and Reliability Process

Examples of leading and lagging Indicators and their relationship with the SMRP Best Practice metrics are provided in Table 1. The metrics are categorized in accordance with the SMRP Body of Knowledge.

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Table 1. Leading and Lagging Indicators

	Behaviors & Processes	Operational Execution	Manufacturing Performance
BoK – Business Management			
Maintenance Margin (COGS)			Lagging
Maintenance Unit Cost			Lagging
Maintenance Cost per RAV			Lagging
BoK – Manufacturing Process Reliability			
OEE			Lagging
Availability			Lagging
Total Operating Time			Lagging
BoK – Equipment Reliability			
Systems Covered by Criticality Analysis	Lagging	Leading	Leading
Scheduled Downtime		Lagging	Lagging
Unscheduled Downtime		Lagging	Lagging
MTBF		Lagging	Leading
BoK – Organization & Leadership			
Rework	Lagging	Leading	Leading
Maintenance Training - $	Lagging	Leading	Leading
Maintenance Training - MHRs	Lagging	Leading	Leading
BoK – Work Management			
Corrective Maintenance Hours		Lagging	Leading
Preventive Maintenance Hours		Lagging	Leading
Condition Based Maintenance Hours		Lagging	Leading
Planned Work	Lagging	Leading	Leading
Reactive Work	Lagging	Lagging	Leading
Proactive Work	Lagging	Lagging	Leading
Schedule Compliance Hours		Leading	Leading
Schedule Compliance Work Orders		Leading	Leading
Standing Work Orders		Leading	Leading
Work Order Aging	Lagging	Leading	Leading
Planned Backlog	Lagging	Leading	Leading

CONCLUSION

The use of leading and lagging indicators is an important component of the maintenance and reliability process. Leading indicators measure the process and are used to predict changes and trends. Lagging indicators measure results and confirm long-term trends. Whether an indicator is a leading or lagging indicator depends on where in the process the indicator is applied. A lagging indicator of one process component can be a leading indicator of another process component. Whether leading or lagging, performance indicators should be used confirm process performance. These indicators help build on successes and can lead to improvement where unfavorable trends exist.

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SMRP GUIDELINE 4.0

4.0 GUIDE TO MEAN METRICS

Published on April 16, 2009

Guidelines provide additional information or further clarification of component terms used in SMRP Best Practice Metrics. This guideline is for group of metrics referred to as the mean metrics.

DEFINITION

The mean metrics are those metrics that describe the reliability, availability and maintainability (RAM) characteristics of a component, asset or facility. The definition of and calculations for each metric is found within the individual metric data sheets.

PURPOSE

The mean metrics are widely used across different industries to assess asset/component health through RAM analysis. These metrics can be compared to other assets, against a standard or trended over time. These metrics can be used to identify improvements to maintenance processes or asset/component designs. The purpose of this guideline is to assist in choosing the appropriate metric for the analysis.

INCLUSIONS

- SMRP Metric 3.5.1 Mean Time Between Failures (MTBF)
- SMRP Metric 3.5.5 Mean Time to Failures (MTTF)
- SMRP Metric 3.5.2 Mean Time to Repair or Replace (MTTR)
- SMRP Metric 3.5.3 Mean Time Between Maintenance (MTBM)

EXCLUSIONS

Other downtime metrics

INTERPRETATION OF MEAN METRICS

The important thing to remember with the mean metrics is when to use the appropriate metric for analysis.

- To understand failures (reliability)
    - Use MTBF for repairable assets and components
    - Use MTTF for non-repairable assets and components
    - Use MTBF and MTTF to evaluate asset/component design from reliability perspective
    - Use failure mode and effects analysis (FMEA) to improve asset/component design from reliability perspective
- To understand maintenance processes (maintainability)
    - Use MTTR for repairable and non-repairable assets and components
    - Use MTBM to evaluate maintenance processes.
    - Use MTTR and MTBM to evaluate asset/component design from maintainability perspective
    - Use root cause failure analysis (RCFA) to improve asset/component design from maintainability perspective
- To understand facility downtime (availability)
    - Use both reliability and maintainability mean metrics since availability can be improved from reliability and maintainability improvements.
    - Analysis should be performed to determine which type of mean metric (reliability or maintainability) should be evaluated first for potential improvements.

REFERENCES

Approved by consensus of SMRP Best Practice Committee.

WORK MANAGEMENT GUIDELINE 5.0

5.0 MAINTENANCE WORK TYPES

Published on April 16, 2009

Guidelines provide additional information or further clarification on component terms used in SMRP Best Practice Metrics. This guideline is for classifying maintenance work by the type of work performed.

DEFINITION

Work types
Classifications of maintenance work according to the nature of work performed.

PURPOSE

Classification of maintenance labor by work type enables analysis of several factors within the work management process, including the effectiveness of the preventive and predictive maintenance programs, the effectiveness of the work management process and the degree to which the organization operates with a proactive philosophy.

MAINTENANCE WORK TYPES

The sum of the four main blocks (labeled All Work) in Figure 1 on the next page should total 100%.

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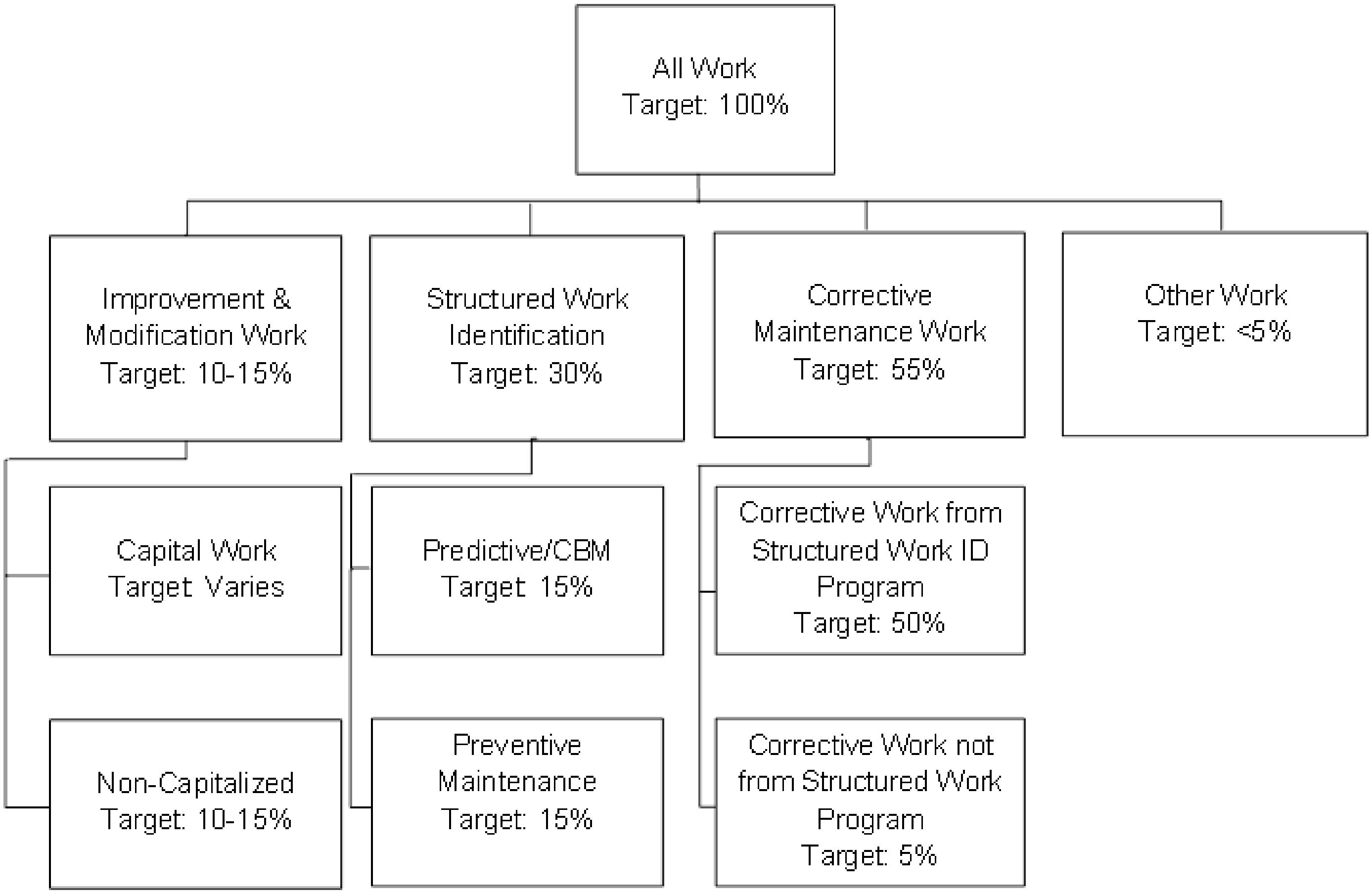

Figure 1. Work Types

Work types depicted in Figure 1 above should not be confused with proactive or reactive work, or with planned or unplanned work, which are discussed later in this guideline document.

COMPONENT DEFINITIONS

All Work

The sum total of maintenance labor consumed during the period (differs from the standard definition of total maintenance labor hours in that it includes labor used for capital expansions and improvements). Examples:

1.1. Improvement and Modification Work – Maintenance labor consumed on plant improvements and expansions, whether that work is capitalized or not.

1.1.1. Capital Work – Maintenance labor used on capital improvement work.

1.1.2. Non-Capitalized Improvements and Modifications – Maintenance labor used on improvements and modifications that are not capitalized, but funded from operating expense.

1.2. Structured Work Identification – Maintenance labor used on planned, programmed routines such as Preventive Maintenance tasks and Predictive Maintenance routes.

1.2.1. Predictive / Condition Based Maintenance – Maintenance labor used to assess the condition of an asset to determine the likelihood of failure before actual failure occurs.

1.2.2. Preventive Maintenance – Maintenance labor used to service, restore or replace an asset on a fixed interval regardless of condition.

1.3. Corrective Maintenance Work – Maintenance work done to restore the function of an asset after failure or when failure is imminent.

1.3.1. Corrective Work from Structured Work Identification Program – Maintenance labor used on corrective work that was identified through preventive and/or predictive maintenance tasks and completed prior to failure in order to restore the function of an asset.

1.3.2. Corrective Work Not from Structured Work Identification Program – Maintenance labor used on corrective work after failure has occurred.

1.4. Other Non-Maintenance Work – Any maintenance labor used for purposes other than those listed above.

RELATED DEFINITIONS

Proactive Work
Maintenance work that is completed to avoid failures or to identify defects that could lead to failures. It includes routine preventive and predictive maintenance activities and work tasks identified from them. Referring to Figure 1, proactive work includes predictive/condition based maintenance, preventive maintenance and corrective work from structured work identification program as defined above.

Reactive Work
Maintenance work that breaks into the weekly schedule. Referring to Figure 1, reactive work may include the emergent and urgent component of corrective work not from structured work identification program, but not necessarily all of it.

Planned Work
Work that has gone through a formal planning process to identify labor, materials, tools, and safety requirements. This information is assembled into a job plan package and communicated to craft workers prior to the start of the work. Referring to Figure 1, planned work usually includes all structured work identification as defined above, and that portion of improvement and modification work, corrective work and other non-maintenance work that has been through the formal planning process.

Unplanned Work
Work that has not gone through a formal planning process. Referring to Figure 1, unplanned work is usually the reactive portion of corrective work, but may also include portions of modification work and other non-maintenance work if that work has not been planned.

Planned work plus unplanned work should total 100%.

APPLICABLE METRICS

- SMRP Metric 5.1.1 Corrective Maintenance Cost
- SMRP Metric 5.1.2 Corrective Maintenance Hours
- SMRP Metric 5.1.3 Preventive Maintenance Cost
- SMRP Metric 5.1.4 Preventive Maintenance Hours
- SMRP Metric 5.1.5 Condition Based Maintenance Costs
- SMRP Metric 5.1.6 Condition Based Maintenance Hours

- SMRP Metric 5.3.1 Planned Work
- SMRP Metric 5.3.2 Unplanned Work
- SMRP Metric 5.4.1 Reactive Work
- SMRP Metric 5.4.2 Proactive Work
- SMRP Metric 5.4.12 PM & PdM Yield

REFERENCES

None

SMRP GUIDELINE 6.0

6.0 DEMYSTIFYING AVAILABILITY

Published on April 16, 2009

Guidelines provide additional information or further clarification of component terms used in SMRP Best Practice Metrics. This guideline provides the various definitions that exist for the term availability.

DEFINITION

Availability is the percentage of time that the asset is actually operating (uptime) compared to when it is scheduled to operate (gross time). This is also called operational availability.

RATIONALE

There are several variations on the definition of availability. SMRP has chosen a definition commonly used at the plant level and that is consistent with the term availability when used as a component of other SMRP metrics (e.g., overall equipment effectiveness (OEE) and total effective equipment performance (TEEP)). When assessing availability, it is important to define the asset boundaries (e.g., machine, system or production line) and to measure operating time (uptime) within that boundary.

OTHER DEFINITIONS

SMRP realizes that the alternate definitions of availability exists and are applied in different contexts (e.g., RAM modeling). A set of these other definitions are provided below for the following availability terms:

- Inherent availability
- Achieved availability
- Operational availability
- Equipment availability
- Point availability
- Average availability
- Limiting availability

Achieved Availability (A_a)

A_a is the probability that an item, when used under design conditions in an ideal support environment, will perform satisfactorily. It includes both active repair time and preventive maintenance time, but excludes administrative and logistic delay times. Thus, it represents the steady-state availability when maintenance downtime, including shutdowns, is considered. Achieved availability is expressed by the formula:

A_a = MTBM / (MTBM + MDTM)

Where MTBM = Mean Time between Maintenance
And MDTM = Mean Downtime for Maintenance

Average Availability (A_t)

(A_t) is the average availability over a specific time period when an asset is available for use. It is also called mean availability, and is expressed by the formula:

$$A_t = \frac{1}{t_2 - t_1} \int_0^t A(u)du$$

Where A(u) = Probability of being available during time (u)
t_1 = Beginning of time period
And t_2 = End of time period

Equipment Availability

A term defined by The Association for Manufacturing Technology as the percentage of potential production time during which equipment is operable. The term is applied to a single piece of manufacturing equipment (or several machines acting as a unit). Equipment availability is expressed by the formula:

Equipment Availability = [Production Time / Potential Production Time] x 100

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Inherent Availability (A_i)

A_i is a measure of the variables inherent in the design that affect availability. In the calculation of downtime, it usually includes only active repair time. It does not include preventive maintenance time and administrative or logistic delays, but does include corrective maintenance downtime. It is usually calculated during the engineering design of equipment and can be used as a measure of performance between planned shutdowns. Inherent availability is expressed by the formula:

A_i = MTBF / (MTBF + MTTR)

Where MTBF = Mean Time between Failures
And MTTR = Mean Time to Repair (corrective maintenance only)

Limiting Availability ($A_=$)

A_∞ is the limit of the point availability function as time approaches infinity. It is also called steady-state availability and is expressed by the formula:

$$A_\infty = \lim_{t \to \infty} A_t$$

Operational Availability (A_o)

A_o is the probability that an item, when used under design conditions in an operational environment, will perform satisfactorily. It includes active repair time, preventive maintenance time and administrative and logistic delays and represents the availability that is actually experienced. Operational availability is expressed by the formula:

A_o = MTBM / (MTBM + MDT)

Where MTBM = Mean Time between Maintenance and MDT = Mean Down Time

Point Availability (A_t)

A_t is the probability that a device, system or component will be operational at any random point in time. It is also called instantaneous availability and is expressed by the formula:

$$A_t = R(t) + \int_0^t R(t-u)m(u)du$$

Where R(t) = Probability of operating during time (t)
m(u) = The renewal density function
And u = The last repair time ($0 < u < t$)

APPLICABLE METRICS

Availability is used in the following metrics:

- 2.1.1 Overall Equipment Effectiveness (OEE)
- 2.1.2 Total Effective Equipment Performance (TEEP)
- 2.2 Availability

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SMRP GUIDELINE 7.0

7.0 MEASURING MAINTENANCE TRAINING RETURN ON INVESTMENT (ROI)

Published on April 16, 2009

Guidelines provide additional information or further clarification of component terms used in SMRP Best Practice Metrics. This guideline is for measuring the return on investment (ROI) for maintenance training.

DEFINITION

Maintenance training ROI is the ratio of the benefit to the cost of training maintenance employees.

OBJECTIVES

Management usually requires that new or additional maintenance training be justifiable from a cost benefit standpoint. The question posed is, "What will be the return on this investment?" This can be difficult to calculate, since the results of the training are not always directly measurable in dollars. The purpose of this guideline is to provide a useable method of demonstrating a return on training investment.

METHODS

The first step is to identify an opportunity for improvement in a process that involves human interaction. This is best accomplished by establishing and tracking related indicators. For example, if lubrication routes take longer to complete than expected, a metric of man-hours per route could be established.

Next, identify opportunities for improvement of the metric. In the example, identify ways to reduce the man-hours per route. Establish specific goals and objectives for the improvement.

These are used initially as the rationale for providing training, and subsequently, in the development of the training program itself.

Identify skill deficiencies of the lubrication technician that may be contributing to the long route times. Perhaps he/she is not utilizing proper techniques when checking levels, drawing samples or lubricating. This can be accomplished by standard testing or through observation by a seasoned technician and/or certified lubrication specialist, a person who would be knowledgeable in the correct methods and procedures.

Develop a training program that will achieve the objectives that have been defined to improve the metric. The program should be tailored to achieve the goals and objectives, which may include things such as proper route management, standardized times, efficient time use, proper sampling techniques, etc.

Conduct the training and evaluate to ensure the objectives are achieved with either a written examination, or in the case of a lubrication route, by the instructor observations. Keep track of the training costs.

Continue to monitor the metric, in this case man-hours per route, and record the change from the same metric before the training took place. The difference between the before-training and after-training metric represents the quantifiable improvement.

Convert this difference into a cost savings by using a cost per man-hour.

Dividing this demonstrated savings by the training cost and multiplying by 100 will yield the maintenance training ROI.

The overall process is depicted in Figure 1.

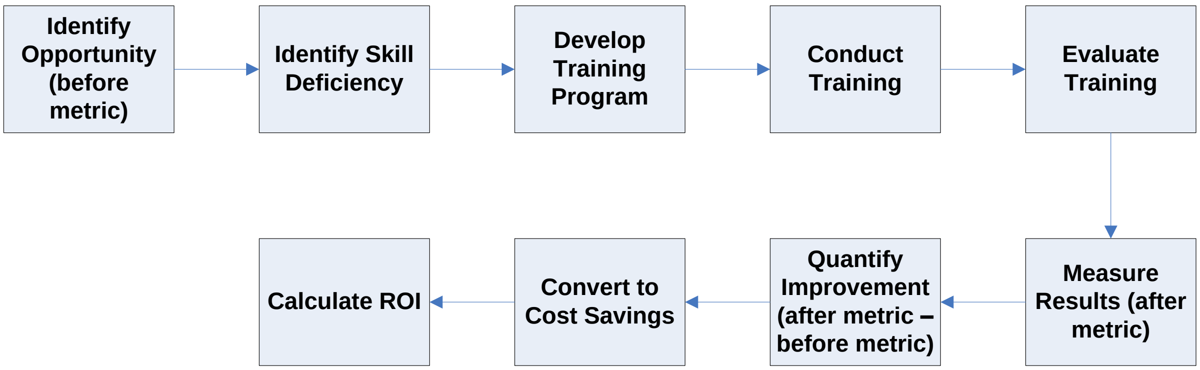

Figure 1. The Maintenance Training ROI Process.

APPLICABILITY

Although the example used is a lubrication route, it can be applied to any process were insufficient skills are contributing to inefficiencies. The key is to establish an appropriate metric and to measure the before-and after-training results.

It is important to apply the method consistently in training program development and implementation. Once a track record of positive ROI has been established, management will be less reluctant to approve the costs for future maintenance training.

APPLICABLE METRICS

The method of measuring maintenance training return on investment is used in SMRP Metric 4.2.3 Maintenance Training ROI.

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Glossary

MAINTENANCE & RELIABILITY BODY OF KNOWLEDGE

Society for Maintenance & Reliability Professionals

ABC Classification
The method of classifying items involved in a decision situation on the basis of their relative importance. Its classification may be on the basis of monetary value, availability of resources, variations in lead-time, part criticality to the running of a facility and other factors.
Used in Benchmarking Survey (BM Survey)

Achieved Availability (A_a)
A_a is the probability that an item, when used under design conditions in an ideal support environment, will perform satisfactorily. It includes both active repair time and preventive maintenance time, but excludes administrative and logistic delay times. Thus, it represents the steady-state availability when maintenance downtime, including shutdowns, is considered. Achieved availability is expressed by the formula:

A_a = MTBM / (MTBM + MDTM)

Where MTBM = Mean Time between Maintenance
And MDTM = Mean Downtime for Maintenance
Used in Guideline 6.0

Active Work Order
Any work order that is not closed in the maintenance management system (MMS).
Used in 5.4.11 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Orders Overdue

Actual Cost to Planning Estimate (5.3.3)
This metric is the ratio of the actual cost incurred on a work order to the estimated cost for that work order.
Used in 5.3.3 Actual Cost to Planning Estimate

Actual Hours to Planning Estimate (5.3.4)
This metric is the ratio of the actual number of labor hours reported on a work order to the estimated number of labor hours that were planned for that work order.
Used in 5.3.4 Actual Hours to Planning Estimate

Actual Preventive Maintenance (PM) & Predictive Maintenance (PdM) Interval
The actual interval or cycle for the repeated completion of a given preventive (PM) or predictive maintenance (PdM) task work order, measured in hours, days or months.
Used in 5.4.10 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Order Compliance

Actual Production Rate
The rate at which an asset actually produces product during a designated time period.
Used in 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 Total Effective Equipment Performance (TEEP)

Actual Work Order Cost
The final cost of the work order after it is closed.
Used in 5.3.3 Actual Cost to Planning Estimate, 5.3.5 Planning Variance Index

Actual Work Order Hours
The quantity of hours reported on a work order after it is closed.
5.3.4 Actual Hours to Planning Estimate

Administrative Idle Time
The time that an asset is not scheduled to be in service due to a business decision (e.g., economic decision).
Used in 2.4 Idle Time

Administrative Meetings
Scheduled and unscheduled meetings, including safety meetings, information meetings and department meetings.
Used in 5.6.1 Wrench Time

Airborne Ultrasonic
A technology that utilizes ultrasound to locate a variety of potential problems in plants and facilities. This technology helps in leak detection, mechanical inspection of pipes and pumps and electrical inspection. It is used for condition monitoring, energy conservation and quality assurance programs. The three main problem areas in which airborne ultrasonic technology are applied include: leak detection, mechanical inspection/trending and electrical inspection. Instruments based on airborne ultrasound sense high frequency sounds produced by leaks, electrical emissions and mechanical operations. Through an electronic process, these sounds are translated into the audible range where they are heard through headphones and observed as intensity increments, typically decibels, on a display panel.
Used in BM Survey

Annual Maintenance Cost
Annual maintenance cost is the annual expenditures for maintenance labor, including maintenance performed by operators (e.g., total productive maintenance (TPM), materials, contractors, services and resources). Includes all maintenance expenses for outages,

shutdowns or turnarounds, as well as normal operating times. Includes capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include capital expenditures for plant expansions or improvements. When calculating, ensure maintenance expenses included are for the assets included in the replacement asset value (RAV) in the denominator.
Used in 1.5 Annual Maintenance Cost as a Percentage of Replacement Asset Value (RAV)

Annual Maintenance Cost as a Percent of Replacement Asset Value (RAV) (1.5)
This metric is the amount of money spent annually maintaining assets, divided by the replacement asset value (RAV) of the assets being maintained, expressed as a percentage.
Used in 1.5 Annual Maintenance Cost as Percent of Replacement Asset Value

All Work
The sum total of maintenance labor consumed during the period (differs from the standard definition of total maintenance labor hours in that it includes labor used for capital expansions and improvements).
Used in Guideline 5.0

Autonomous Work Teams
A small group of people who are empowered to manage themselves and the work they do on a day-to-day basis. The members of an autonomous work group are usually responsible for a whole process, product or service. They not only perform the work, but also design and manage it.
Used in BM Survey

Availability (2.2)
This metric is the percentage of time that the asset is actually operating (uptime) compared to when it is scheduled to operate. This is also called operational availability.
Used in 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 total Effective Equipment Performance (TEEP), 2.2 Availability

Availability (component)
The percentage of the time that the asset is actually operating (uptime) compared to when it is scheduled to operate. Also called operational availability.
Used in 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 Total Effective Equipment Performance (TEEP), 2.2 Availability

Average Availability (A_t)
(A_t) is the average availability over a specific time period when an asset is available for use. It is also called mean availability, and is expressed by the formula:

$$A_t = \frac{1}{t_2 - t_1} \int_0^t A(u)du$$

Where A(u) = Probability of being available during time (u)
t_1 = Beginning of time period
And t_2 = End of time period
Used in Guideline 6.0

Best Production Rate
The rate at which an asset is designed to produce product during a designated time period or the demonstrated best sustained rate, whichever is higher.
Used in 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 Total Effective Equipment Performance (TEEP)

Break Time
Time for scheduled and unscheduled breaks.
Used in 5.6.1 Wrench Time

Business Benefits
The financial benefits that impact the business, such as increases in worker productivity, improved work quality, reduced injuries and incidents and other related direct cost savings caused by an investment in training maintenance employees. Benefits must be translated into a cost benefit.
Used in 4.2.3 Maintenance Training ROI

Centralized Maintenance Organization
An organization wherein a single maintenance department is responsible for the entire facility reporting at the plant level.
Used in BM Survey

Combination Maintenance Organization
A combination or "hybrid" organization structure in which the best characteristics of both centralized and decentralized models are utilized. In this structure, areas will have a dedicated small staff to take care of daily /routine issues and centralized staff will be responsible major PMs and specialized repairs.
Used in BM Survey

Completion Date
The date that preventive maintenance (PM) or predictive maintenance (PdM) work order was certified complete and closed out in the maintenance management system (MMS) system.
Used in 5.4.14 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Compliance

Condition Based Maintenance (component)
An equipment maintenance strategy based on measuring the condition of equipment against known standards in order to assess whether it will fail during some future period and taking appropriate action to avoid the consequences of that failure. The condition of the equipment could be measured using condition monitoring, statistical process control, equipment performance or through the use of human senses. The terms condition based maintenance (CBM), on-condition maintenance and predictive maintenance (PdM) can be used interchangeably.
Used in 5.1.5 Condition Based Maintenance Cost, 5.1.6 Condition Based Maintenance Hours

Condition Based Maintenance Cost (5.1.5)
This metric is the percentage of maintenance labor hours used to measure, trend and compare equipment conditions against known standards to detect, analyze and correct problems before they cause functional failures.
Used in 5.1.5 Condition Based Maintenance Cost

Condition Based Maintenance Cost (component)
The cost that is used to measure the condition of equipment against known standards in order to assess whether it will fail during some future period.
Used in 5.1.5 Condition Based Maintenance Cost

Condition Based Maintenance Hours (5.1.6)
This metric is the percentage of maintenance labor hours used to measure, trend and compare equipment conditions against known standards to detect, analyze and correct problems before they cause functional failures.
Used in 5.1.6 Condition Based Maintenance Hours

Condition Based Maintenance Hours (component)
The percentage of maintenance labor hours used to measure, trend and compare equipment conditions to detect, analyze and correct problems before they cause functional failures.
Used in 5.1.6 Condition Based Maintenance Hours

Condition Based Maintenance Labor Hours (component)
The maintenance labor hours used to measure, trend and compare equipment conditions against known standards to detect, analyze and correct problems before they cause functional failures.
Used in 5.1.6 Condition Based Maintenance Hours

Consignment Stock
The inventoried items that are physically stored in the storeroom, but are owned by the vendor or supplier until issued or consumed.
Used in 5.5.35 Storeroom Transactions, 5.5.36 Storeroom Records

Contact Ultrasonic
Direct contact ultrasonic method places the transducers against the outside of the targeted component. An ultrasonic signal or sound pulse is passed into the component producing an echo read by a receiver. The characteristic of the echo helps identify discontinuities within the component.
Used in BM Survey

Continuous Improvement
An ongoing evaluation program that includes constantly looking for the "little things" that can make a company more competitive. It's a measure of all work that increases or improves the current operating perimeters.
Used in BM Survey

Continuous Improvement Hours (5.7.1)
This metric is the percentage of labor hours of maintenance employees used on continuous improvement activities.
Used in 5.7.1 Continuous Improvement Hours

Contractor Cost (5.5.71)
This metric is the percentage of contractor costs of the total maintenance costs used to maintain assets.
Used in 5.5.71 Contractor Cost

Contractor Hours (5.5.72)
This metric is the percentage of contractor labor hours out of the total maintenance labor hours used to maintain assets.
Used in 5.5.72 Contractor Hours

Contractor Labor Hours
The hours used by contractors performing maintenance on the site. This includes all hours for routine service work, as well as those used on outages, shutdowns or turnarounds. Includes contractor hours used for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include contractor hours used for capital expenditures for plant expansions or improvements.
Used in 5.5.72 Contractor Hours

Contractor Maintenance Cost
The total expenditures for contractors engaged in maintenance on site. Includes all contractor maintenance labor and materials costs for normal operating times, as well as outages, shutdowns or turnarounds. It also includes contractors used for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include contractors used for capital expenditures for plant expansions or improvements.
Used in 5.5.71 Contractor Cost

Contributing Time
The time that is directly related to accomplishing the assigned work including field level risk assessments, instruction time, loaded travel (transporting materials or tools) site cleanup, returning equipment to service and shift hand-over. This time is required to complete the work however is not included in the wrench time calculation.

Used in 5.6.1 Wrench Time Percentage

Corrective Maintenance Cost (5.1.1)
This metric is the percentage of total maintenance cost that is used to restore equipment to a functional state after a failure or when failure is imminent.
Used in 5.1.1 Corrective Maintenance Cost

Corrective Maintenance Costs (component)
The labor, material, services and/or contractor cost for work done to restore the function of an asset after failure or when failure is imminent. Includes operator costs if all operator maintenance costs are included in total maintenance cost.
Used in 5.1.1 Corrective Maintenance Cost

Corrective Maintenance Hours (5.1.2)
This metric is the percentage of total maintenance labor that is used to restore equipment to a functional state after a failure-finding task indicated a functional failure or when functional failure is imminent or has already occurred.
Used in 5.1.2 Corrective Maintenance Hours

Corrective Maintenance Labor Hours (Component)
The labor hours are the labor hours used to restore the function of an asset after failure or when failure is imminent. Labor can be internal and/or external (contract).
Used in 5.1.2 Corrective Maintenance Hours

Corrective Work
Work done to restore the function of an asset after failure or when failure is imminent.
Used in 4.1 Rework

Corrective Work Identified from Preventive and Predictive Maintenance Work Orders
Work identified from preventive maintenance (PM) and predictive maintenance (PdM) work orders is work that was identified through PM and/or PdM tasks and completed prior to failure in order to restore the function of an asset.
Used in 5.4.2 Proactive Work, 5.4.12 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Yield

Craft-Wage Headcount
The number of maintenance personnel responsible for executing work assignments pertaining to maintenance activities. Includes the number of contractors' personnel who are used to supplement routine maintenance. The headcount is measured in full-time equivalents (FTE).
Used in 1.1 Ratio of Replacement Asset Value (RAV) to Craft-Wage Head Count

Craft Worker
See Maintenance Craft Worker.

Craft Worker on Shift Ratio (5.5.6)
This metric is the ratio of the number of maintenance craft workers on shift whose primary function is to respond to unexpected failures versus the total number of maintenance craft workers.
Used in 5.5.6 Craft Worker on Shift Ratio

Craft Worker to Planner Ratio (5.5.2)
This metric is the ratio of maintenance craft workers to planners.
Used in 5.5.2 Craft Worker to Planner Ratio

Craft Worker to Supervisor Ratio (5.5.1)
This metric is the ratio of maintenance craft workers to supervisors.
Used in 5.5.1 Craft Worker to Supervisor Ratio

Crew Capacity
The portion of the weekly maintenance labor complement that is available to work on backlog jobs. It is the sum of the straight time hours per week for each individual in the crew, plus scheduled overtime, less indirect commitments (e.g., training, meetings, vacations, etc.).
Used in 5.4.8 Planned Backlog, 5.4.9 Ready Backlog

Critical Equipment
Equipment that has been evaluated and classified as critical due to its potential impact on safety, environment, quality, production and cost.
Used in BM Survey

Critical Stock Item
An item that is inventoried because having the part on-hand is considered essential to the overall reliability of the operation due to its high cost, long lead time and/or negative impact on a plant's safety, environmental impact, operation and/or downtime should the part be needed and not be in stock. Also called critical, emergency or insurance spares.
Used in 5.5.34 Inactive Stock, 5.5.36 Storeroom Record Rank

Critical Systems
The systems that are vital to continued operations, will significantly impact production or have inherent risks to personnel safety or the environment should they fail.
Used in 3.1 Systems Covered by Critical Analysis, 5.4.10 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Order Compliance

Criticality Analysis
A quantitative analysis of events and faults and the ranking of these in order based on a weighted combination of the seriousness of their consequences and frequency of occurrence.
Used in 3.1 Systems Covered by Critical Analysis, 5.4.10 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Order Compliance, 5.4.11 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Orders Overdue

Current Date
The current calendar date that the report is run.
Used in 5.4.11 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Orders Overdue

Current Interval Hours
The number of actual hours on a piece of equipment since the last preventive maintenance (PM) or predictive maintenance (PdM) was performed.
Used in 5.4.11 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Orders Overdue

Days
Calendar days versus operating days/time.
Used in 5.4.11 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Orders Overdue

Decentralized Maintenance Organization
An organization in which multiple maintenance groups report to specific business or production functions.
Used in BM Survey

Defective Units Produced
The number of unacceptable units produced during a time period (e.g., losses, rework, scrap, etc.).
Used in 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 Total Effective Equipment Performance (TEEP)

Direct Contract Maintenance Personnel
Maintenance workers who are not company employees, but are hired or provided by an outside company to perform actual maintenance tasks, such as corrective and preventive maintenance. Examples include contract mechanics, electricians and hourly technicians.
Used in 5.5.3 Direct to Indirect Maintenance Personnel Ratio

Direct Maintenance Personnel
Maintenance employees assigned to perform actual maintenance tasks, such as corrective and preventive maintenance. Examples include mechanics, electricians, pipe fitters, mobile equipment operators and hourly technicians.
Used in 5.5.3 Direct to Indirect Maintenance Personnel Ratio

Direct Purchase Item
Non-inventoried items, typically purchased on an as-needed basis.
Used in 5.5.35 Storeroom Transactions

Direct to Indirect Maintenance Personnel Ratio (5.5.3)
This metric is the ratio of the maintenance personnel who are actively doing the maintenance work (direct) to the maintenance personnel supporting the maintenance work (indirect). Direct personnel include those workers in the maintenance department that repair, maintain, modify or calibrate equipment. Indirect personnel support the maintenance work with administration, planning, stores, condition monitoring and supervision.
Used in 5.5.3 Direct to Indirect Maintenance Personnel Ratio

Downtime Event
An event when the asset is down and not capable of performing its intended function.
Used in 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 Total Effective Equipment Performance (TEEP), 3.5.4 Mean Downtime (MDT)

Due Date
The required completion date of the preventive maintenance (PM) or predictive maintenance (PdM), including the grace period.
Used in 5.4.11 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Orders Overdue, 5.4.14 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Compliance

Economic Order Quantity (EOQ)
A fixed order quantity is established that minimizes the total of carrying and preparation costs under conditions of certainty and independent demand.
Used in BM Survey

Equipment Availability
A term defined by The Association for Manufacturing Technology as the percentage of potential production time during which equipment is operable. The term is applied to a single piece of manufacturing equipment (or several machines acting as a unit). Equipment availability is expressed by the formula:

Equipment Availability = [Production Time / Potential Production Time] x 100
Used in Guideline 6.0

Equipment Repair History
A chronological list of failures, repairs and modifications on equipment/assets. Also called maintenance history or maintenance record.
Used in BM Survey

Estimated Replacement Value (ERV)
Also referred to as Replacement Asset Value (RAV), it is the dollar value that would be required to replace the production capability of the present assets in the plant. Includes production/process equipment, as well as utilities, facilities and related assets. Does not use the insured value or depreciated value of the assets. Includes the replacement value of buildings and grounds if these assets are included in maintenance expenditures. Does not include the value of real estate, only improvements.
Used in 1.1 Ratio of Replacement Asset Value (RAV) to Craft-Wage Headcount, 1.4 Stocked Maintenance, Reliability and Operating Materials (MRO) Inventory Value as a Percentage of Replacement Asset Value (RAV), 1.5 Annual Maintenance Cost as a Percentage of Replacement Asset Value (RAV)

Execution Date
The date the preventive maintenance (PM) or predictive maintenance (PdM) work was executed on the asset or component.
Used in 5.4.14 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Compliance

Failure
When an asset is unable to perform its required function.
Used in 3.5.1 Mean Time between Failures (MTBF), 3.5.2 Mean Time to Repair (MTTR), 3.5.5 Mean Time to Failures (MTTF), 5.4.2 Proactive Work

Failure Modes and Effects Analysis (FMEA)
A procedure in which each potential failure mode in every sub-item (component) of an item (asset) is analyzed to determine its effect on other sub-items and on the required function of the item.
Used in BM Survey, SMRP Guideline 4.0 – Guide to Mean Metrics

Fatalities
The number of fatalities in your company during the past year. For US companies, this number is reported on section G of OSHA form 300A.
Used in BM Survey

First Aid
Injuries or illnesses that do not meet the minimum threshold to be recordable. The incident rate is calculated by taking the total number of "first aid incidents" times 200,000 and dividing the result by the number of hours of exposure.
Used in BM Survey

Free Issue Inventory
Low cost and high usage inventoried stock items that are available as needed without a goods issue transaction. Typically, these items are stored in a secured environment close to the point of usage. Examples of common free issue inventoried stock include nuts, bolts, gaskets, cable ties, etc.
Used in 5.5.36 Storeroom Record

Group Leader
A team member who may not have any authority over other members, but is appointed on a permanent or rotating basis to represent the team to the next higher reporting level, make decisions in the absence of a consensus, resolve conflict between team members and coordinate team efforts.
Used in BM Survey

Idle Time (2.4)
This metric is the amount of time an asset is idle or waiting to run. It is the sum of the times when there is no demanded administrative idle time (e.g., not scheduled for production). Does not include equipment downtime (scheduled or unscheduled) and no feedstock or raw materials.
Used in 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 Total Effective Equipment Performance (TEEP), 2.2 Availability, 2.3 Uptime, 2.4 Idle Time, 2.5 Utilization Time

Idle Time (component)
The time an asset is idle or waiting to run. The sum of the times when there is no demanded administrative idle time (e.g., not scheduled for production). Does not include equipment downtime (scheduled or unscheduled) and no feedstock or raw materials.
Used in 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 Total Effective Equipment Performance (TEEP), 2.2.Availablity, 2.3 Uptime, 2.4 Idle Time, 2.5 Utilization Time

Inactive Inventory Stock Record
An inventoried maintenance, operating and repair (MRO) storeroom item with no usage for 12 months or longer.
Used in 5.5.34 Inactive Stock, 5.5.36 Storeroom Records

Inactive Inventory Stock Value
The current book value of maintenance, repair and operating supplies (MRO) in stock with no usage for 12 or more months, including consignment and vendor-managed stores. Includes the value of inactive MRO materials in all storage locations, including satellite and/or remote storeroom locations whether or not that material is included in inventory asset accounts or an allocated portion of pooled spares. Also includes estimated value for stocked material that may be in stock at zero value because of various maintenance management systems (MMS) and/or accounting idiosyncrasies, etc. Does not include raw material, finished goods, packaging materials and related materials.
Used in 5.5.34 Inactive Stock

Inactive Stock (5.5.34)
This metric is the ratio of the number of inactive maintenance, repair and operating (MRO) inventory stock records to the total number of MRO inventory stock records excluding critical spares and non-stock inventory records.
Used in 5.5.34 Inactive Stock

Indirect Contract Maintenance Personnel
Maintenance personnel are maintenance workers, who are not company employees, but hired or provided by an outside company to support the contracted maintenance services, and are not directly performing maintenance work. Examples include contract supervision, engineering, maintenance planning and scheduling, inspection, clerical, etc.
Used in 5.5.3 Direct to Indirect Maintenance Personnel Ratio

Indirect Maintenance Personnel
Maintenance employees required to support the overall maintenance operation, but not directly performing maintenance work. These personnel are generally charged to an overhead account. Examples include supervision, engineering, maintenance planning and scheduling, clerical, etc.
Used in 5.5.3 Direct to Indirect Maintenance Personnel Ratio, 5.5.4 Indirect Maintenance Personnel Cost

Indirect Maintenance Personnel Cost (5.5.4)
This metric is the cost incurred for indirect maintenance personnel for the period, expressed as a percentage of the total maintenance cost for the period.
Used in 5.5.4 Indirect Maintenance Personnel Cost

Indirect Maintenance Personnel Cost (component)
All maintenance labor costs, both straight, overtime and payroll added cost, such as taxes or insurance contributions. Does not include labor for these individuals that is used for capital expenditures or contractor labor cost.
Used in 5.5.4 Indirect Maintenance Personnel Cost

Infrared Monitoring
A monitoring technique that uses special instruments, such as an infrared camera, to detect, identify and measure the heat energy objects radiate in proportion to their temperature and emissivity.
Used in BM Survey

Inherent Availability (A_i)
A_i is a measure of the variables inherent in the design that affect availability. In the calculation of downtime, it usually includes only active repair time. It does not include preventive maintenance time and administrative or logistic delays, but does include corrective maintenance downtime. It is usually calculated during the engineering design of equipment and can be used as a measure of performance between planned shutdowns. Inherent availability is expressed by the formula:

A_i = MTBF / (MTBF + MTTR)

Where MTBF = Mean Time between Failures
And MTTR = Mean Time to Repair (corrective maintenance only)
Used in Guideline 6.0

In-sourcing Maintenance
The process of moving maintenance activities performed by outside contractors in-house to be performed by company employees. This is the opposite of outsourcing.
Used in BM Survey

Instruction Time
The time when a maintenance craft worker is receiving work instruction (e.g., assignment of jobs at the beginning of a shift).
Used in 5.6.1 Wrench Time

Internal Maintenance Employees
All personnel, salaried and hourly, direct and indirect, who are responsible for executing work assignments pertaining to the maintenance of physical assets and components. Same as maintenance employee.
Used in 4.2.1 Maintenance Training Cost, 4.2.3 Maintenance Training ROI

Internal Maintenance Personnel Cost (5.5.5)
This metric is the total burdened cost incurred for plant maintenance employees for the period, expressed as a percentage of the total maintenance cost for the period.
Used in 5.5.5 Internal Maintenance Personnel Cost

Internal Maintenance Personnel Cost (component)
All internal maintenance labor costs, including benefits, both straight time and overtime. Internal maintenance personnel are plant employees only, not contractors. Includes maintenance labor costs for normal operating times, as well as outages, shutdowns or turnarounds. Includes labor for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Includes the cost for staff overhead support (supervisors, planners, managers, storeroom personnel, etc.). Also includes the cost for maintenance work done by operators. Does not include labor used for capital expenditures for plant expansions or improvements, just as it does not include contractor labor cost or janitorial cost.
Used in 5.5.5 Internal Maintenance Personnel Cost

Inventory Stock Record
The individual record describing the part that is inventoried, represented by a unique inventory number or stock keeping unit (SKU).
Used in 5.5.34 Inactive Stock, 5.5.36 Storeroom Records

Inventory Stock Value
The current book value of MRO supplies in stock, including consignment and vendor-managed inventory. Includes the value of MRO materials in all storage locations, including satellite and/or remote storeroom locations whether or not that material is included in inventory asset accounts or an allocated portion of pooled spares. Estimates the value of "unofficial" stores in the plant even if they are not under the control of the storeroom and even if they are not "on the books". Includes estimated value for stocked material that may be in stock at zero value because of various maintenance management systems and/or accounting idiosyncrasies, etc. Does not include raw material, finished goods, packaging materials and related materials.
Used in 5.5.34 Inactive Stock Change

Knowledge Management System
A system that is designed to capture the explicit knowledge of a company's employees, contractors and other people working on-site on a permanent or temporary basis.
Used in BM Survey

Labor Costs
Refer to Total Maintenance Labor Cost.

Labor Hours on Job Plans
The planner's estimate of labor hours required to complete a work order at the point when the planning is complete and the work order is sent for approval.
Used in 5.3.6 Planner Productivity

Lagging Indicator
An indicator that measures performance after the business or process result starts to follow a particular pattern or trend. Lagging indicators confirm long-term trends, but do not predict them.
Used in Guideline 3.0

Leading Indicator
An indicator that measures performance before the business or process result starts to follow a particular pattern or trend. Leading indicators can sometimes be used to predict changes and trends.
Used in Guideline 3.0

Lean Initiatives
Business improvement initiatives that are designed to remove waste from the business processes. The waste may include materials, time, scrap, poor quality, no value add tasks, buffers and work-in-progress.
Used in BM Survey

Limiting Availability ($A_{=}$)
A_{∞} is the limit of the point availability function as time approaches infinity. It is also called steady-state availability and is expressed by the formula:

$$A_{\infty} = \lim A_t$$
$$t \rightarrow \infty$$
Used in Guideline 6.0

Line Items in Inventory
The number of different items in inventory, each with its own unique description and stock number.
Used in BM Survey

Lost Time Incident Rate
Calculated by taking the total number of lost time incidents, multiplying it by 200,000 and dividing the result by the number of hours of exposure. Note: 200,000 is an arbitrary number established by OSHA 1904.7 and is supposed to represent the hours worked in a year by 100 employees – 100 employees multiplied by 50 weeks per year multiplied by 40 hours per week.
Used in BM Survey

Lube Oil Analysis
Performed to ensure the quality of lubricant. An analytic technique used to determine and identify problems with the lubricant and machine condition based upon quantitative and qualitative measurement of particles suspended in lubricating fluids. The magnitude of the concentration level is a measure of wear in an oil-wetted mechanism and the elements present to identify the worn components. A predictive technique used to identify machine wear and quantify lubricant condition. A sample of oil is subjected to a series of tests to determine whether the lubricant properties have deteriorated and/or the machine components wear. Tests can include any of the following: ICP Spectroscopy, Particle Count Testing, Viscosity Testing, Ferrography, Acid and Base Number, Karl Fischer Water Test, Varnishing Potential, etc. Oil analysis can identify machine wear before detection by other predictive technologies (such as vibration).
Used in BM Survey

Maintenance
The set of actions taken to ensure that systems, equipment and components provide their intended functions when required. The primary focus of this definition is on maintaining the intended function of an item rather than its design performance. Many designs provide excess performance capacity or endurance as an inherent characteristic of the design. (e.g., the pump selected for a system may be rated at 100 gpm when the system design requirement is only 75 gpm.) Maintenance that is oriented to sustaining excess capability not needed for operations expends resources without benefit. This is not good maintenance practice. This definition requires the function being maintained to be available when it is required. Since certain functions, such as weapons firing and overpressure relief, may not be required continuously, there may be a need to verify their availability. The terms "component, equipment, and systems" as used in this definition apply to hardware at the particular level where the analysis is

being performed. This may be a system, a subsystem, equipment, or a component, depending on the specific task being examined.
Used in U.S. Navy

Maintenance Action
One or more tasks necessary to retain an item in, or restore it to, a specified operating condition. A maintenance action includes corrective, as well as preventive and predictive, maintenance tasks that interrupt the asset function.
Used in 3.5.3 Mean Time between Maintenance (MTBM)

Maintenance Budget Compliance
The comparison at a given frequency (monthly, quarterly or annually) of the planned versus actual maintenance spend. Usually expressed as a percentage.
Used in BM Survey

Maintenance Contract Employees
All personnel, salaried and hourly, direct and indirect, who are hired or provided by an outside company and are responsible for executing work assignments pertaining to the maintenance of physical assets and components.
Used in 5.5.3 Direct to Indirect Maintenance Personnel Ratio

Maintenance Craft Worker
The worker responsible for executing maintenance work orders (e.g., electrician, mechanic, PM/PdM technician, etc.).
Used in 5.5.1 Craft Worker to Supervisor Ratio, 5.5.2 Craft Worker to Planner Ratio, 5.5.6 Craft Worker on Shift Ratio

Maintenance Employees
All personnel, salaried and hourly, direct and indirect, who are responsible for executing work assignments pertaining to the maintenance of physical assets and components. Same as internal maintenance employees.
Used in 4.2.1 Maintenance Training Costs, 4.2.2 Maintenance Training Hours
4.2.3 Maintenance Training ROI, 5.5.3 Direct to Indirect Maintenance Personnel Ratio, 5.7.1 Continuous Improvement Hours

Maintenance Job Plan
Also known as a job plan package, it is the assembly of written and other information that provides guidelines for completing the job safely and efficiently with high quality. Elements to include: labor estimate, material requirements, asset documents, drawings, bills of material,

tool list, applicable procedures and safety related items. Should contain enough information to enable the craftsperson to complete the job without having to spend additional time searching for the information, tools, equipment or material. A minimum job plan includes the work order, labor estimate, material requirements and work order feedback form.
Used in 5.3.6 Planner Productivity

Maintenance Labor Hours Used for Continuous Improvement
Used for continuous improvement are the total direct and indirect maintenance labor hours used on continuous improvement activities. Examples of continuous improvement activities are: lean, six sigma, work process redesign, work practice redesign, work sampling and other similar performance improvement activities. Examples of areas that could be improved include: availability, reliability, maintainability, quality, productivity, safety, environment and costs. Do not include labor hours for capital expenditures for plant expansions or improvements.
Used in 5.7.1 Continuous Improvement Hours

Maintenance Materials Cost (5.5.38)
This metric is the total cost incurred for materials, supplies and consumables needed to repair and maintain plant and facility assets for a specified time period, expressed as a percentage of the total maintenance cost for the period.
Used in 5.5.38 Maintenance Materials Cost

Maintenance Materials Cost (component)
The cost of all maintenance, repair and operating material (MRO) used during the specified time period. Includes stocked MRO inventory usage, outside purchased materials, supplies, consumables and the costs to repair spare components. Also includes materials used for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include material used for capital expenditures for plant expansions or improvements.
Used in 5.5.38 Maintenance Materials Cost

Maintenance Shutdown Cost (5.1.9)
This metric is the total cost incurred in association with a planned maintenance shutdown expressed as a percentage of the total maintenance cost for the period in which the shutdown(s) occurred.
Used in 5.1.9 Maintenance Shutdown Cost

Maintenance Shutdown Cost (component)
The total cost incurred to prepare and execute all planned maintenance shutdown or outage activities. Includes all staff costs incurred for planning and management of the maintenance

activities performed during the shutdown. Includes all costs for temporary facilities and rental equipment directly tied to maintenance activities performed during the shutdown. Does not include costs associated with capital project expansions or improvements that are performed during the shutdown. Calculated and reported for a specific time period (e.g., monthly, quarterly, annually, etc.).
Used in 5.1.9 Maintenance Shutdown Cost

Maintenance Training Cost (4.2.1)
This metric is the cost for formal training that internal maintenance employees receive annually. It is expressed as cost per employee.
Used in 4.2.1 Maintenance Training Cost

Maintenance Training Hours (4.2.2)
This metric is the number of hours of formal training that maintenance personnel receive annually. It is expressed as hours per employee.
Used in Maintenance Training Hours

Maintenance Training ROI (4.2.3)
This metric is the ratio of the benefit to the cost of training internal maintenance employees.
Used in 4.2.3 Maintenance Training ROI

Maintenance Unit Cost (1.3)
This metric is the measure of the total maintenance cost required for an asset or facility to generate a unit of production.
Used in 1.3 Maintenance Unit Cost

Mean Downtime (MDT) (3.5.4)
This metric is the average downtime required to restore an asset or component to its full operational capabilities. Mean downtime (MDT) includes the time from failure to restoration of an asset or component, including operations activities such as locking out and cleaning equipment.
Used in 3.5.4 Mean Downtime (MDT)

Mean Life
A term used interchangeably with mean time between failures (MTBF) and mean time to failure (MTTF).
Used in 3.5.1 Mean Time between Failures (MTBF)

Mean Time between Failures (MTBF) (3.5.1)
This metric is the average length of operating time between failures for an asset or component. Meant time between failures (MTBF) is usually used primarily for repairable assets of similar type. Mean time to failures (MTTF), a related term, is used primarily for non-repairable assets and components (e.g., light bulbs and rocket engines). Both terms are used as a measure of asset reliability and are also known as mean life. MTBF is the reciprocal of the failure rate (λ), at constant failure rates.
Used in 3.5.1 Mean Time between Failures (MTBF)

Mean Time between Maintenance MTBM (3.5.3)
This metric is the average length of operating time between one maintenance action and another maintenance action for an asset or component. This metric is applied only for maintenance actions which require or result in function interruption.
Used in 3.5.3 Mean Time between Maintenance (MTBM)

Mean Time to Failure (MTTF) (3.5.5)
This metric is the average length of operating time to failure of a non-repairable asset or component (e.g., light bulbs, rocket engines). Another term, mean time between failures (MTBF), is primarily used for repairable assets and components of similar type. Both terms are a measure of asset reliability and are also known as mean life.
Used in 3.5.5 Mean Time to Failure (MTTF), BM Survey

Mean Time to Repair or Replace MTTR (3.5.2)
This metric is the average time needed to restore an asset to its full operational capabilities after a failure. Mean time to repair or replace (MTTR) is a measure of asset maintainability, usually expressed as the probability that a machine can be restored to its specified operable condition within a specified interval of time regardless of whether an asset is repaired or replaced.
Used in 3.5.2 Mean Time to Repair or Replace MTTR

Meeting Time
Scheduled and unscheduled meetings including safety meetings, information meetings, department meetings and other similar meetings.
Used in 5.6.1 Wrench Time

Motor Current Analysis
Monitoring the motor current during start-up (surge-current) and the current trace over time (decay) to detect friction forces. A predictive technique used to analyze current and voltage supplied to an electric motor or generator to detect abnormal operating conditions in induction

motor applications. Can be used to identify incoming winding health, stator winding health, rotor health, load issues, system load and efficiency, bearing health, air gap static and dynamic eccentricity and coupling health.
Used in BM Survey

Motor Testing (Hi-Pot, Insulation)
Done to confirm the reliability of an electrical insulation system where a high voltage (twice the operating voltage plus 1000 volts) is applied to cables and motor windings. Typically a "go/no-go" test. Industry practice calls for HiPot tests on new and rewound motors only. This test stresses the insulation system and can induce premature failures in marginal motors.
Used in BM Survey

MRO (Maintenance, Repair and Operating Materials)
An acronym to describe maintenance, repair and operating materials (MRO) and spare parts.
Used in 1.4 Stocked Maintenance, Reliability and Operating Materials (MRO) Inventory Value as a Percentage of Replacement Asset Value (RAV)

Necessary Preventive Maintenance (PM) & Predictive Maintenance (PdM) Corrective Work Orders
Work where a defect or a potential failure was identified and corrected as a result of preventive maintenance (PM) and predictive maintenance (PdM) inspections or tasks.
Used in 5.4.13 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Effectiveness

No Demand
The time that an asset is not scheduled to be in service due to the lack of demand for the product.
Used in 2.4 Idle Time

No Feedstock or Raw Materials
The time that an asset is not scheduled to be in service due to a lack of feedstock or raw material.
Used in 3.4 Unscheduled Downtime

Non-Contributing Time
The time not directly related to accomplishing the assigned work (e.g., breaks, personal time, signoff and wash-up, administrative meetings, unloaded travel (not carrying materials or tools), planning, waiting, and training).
Used in 5.6.1 Wrench Time

Non-destructive Testing (NDT)
A collection of technologies that provide a means of assessing the integrity, properties and condition of components or material without damaging or altering them. Methods include: ultrasonic testing, eddy current testing, radiography, thermography, visual inspection, magnetic particle testing, dye penetrate testing, acoustic testing and others. Also termed non-destructive examination (NDE).
Used in BM Survey

Non-Productive Work Time
The time not directly related to accomplishing the assigned work (e.g., breaks, personal time, meetings, travel, planning, instruction, waiting, procuring tools and materials and training).
Used in 5.6.1 Wrench Time

Non-stock Item
An item documented in the inventory system that is not physically in the storeroom, but is documented for use on a parts list and/or for repetitive purchasing purposes. Also referred to as order on request or demand.
Used in 5.5.34 Inactive Stock, 5.5.35 Storeroom Transactions, 5.5.36 Storeroom Records

Number of Inventory Requests with Stock Out
An inventory request is a stock out if the requested item is normally stocked on site and the inventory request is for a normal quantity of the item, but the inventory on hand is insufficient to fill the request.
Used in 5.5.33 Stock Outs

Number of Work Orders Performed as Scheduled
The number of work orders on the maintenance schedule that were executed when scheduled are considered performed as scheduled.
Used in 5.4.4 Schedule Compliance – Work Orders

On Shift
Maintenance craft workers who rotate with or who are assigned work hours aligned with a production shift are considered "on shift." Maintenance craft workers on shift typically work on emergency work and are not identified with the main group of maintenance craft workers that work day shift.
Used in 5.5.6 Craft Worker on Shift Ratio

Operating Time
An interval of time during which the asset or component is performing its required function.
Used in 2.5 Utilization Rate, 3.5.1 Mean Time between Failures (MTBF), 3.5.3 Mean Time between Maintenance (MTBM), 3.5.5 Mean Time between Failures (MTTF)

Operational Availability (A_o)
A_o is the probability that an item, when used under design conditions in an operational environment, will perform satisfactorily. It includes active repair time, preventive maintenance time and administrative and logistic delays and represents the availability that is actually experienced. Operational availability is expressed by the formula:

A_o = MTBM / (MTBM + MDT)

Where MTBM = Mean Time between Maintenance and MDT = Mean Down Time
Used in Guideline 6.0

Operator Maintenance
When operators perform inspections and minor routine and recurring maintenance activities to keep the asset working efficiently for its intended purpose (e.g., cleaning, pressure checks, lube checks etc.).
Used in BM Survey

Operational Availability
The percentage of time that the asset is capable of performing its intended function (uptime plus idle time). Also called availability.
Used in 2.2 Availability, 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 Total Effective Equipment Performance (TEEP)

OSHA Recordable Rate
OSHA Recordable Rate (per 200,000 hrs.) - OSHA Recordable Incident Rate is calculated by taking the total number of "recordable incidents" multiplied by 200,000 and dividing the result by the number of hours of exposure.
Used in BM Survey

Outsourcing Maintenance
The act of having maintenance performed by vendors or outside contractors.
Used in BM Survey

Overall Equipment Effectiveness (OEE) (2.1.1)
This metric is a measure of equipment or asset performance based on actual availability, performance efficiency and quality of product or output when the asset is scheduled to operate. Overall equipment effectiveness (OEE) is typically expressed as a percentage.
Used in 2.1.1 Overall Equipment Effectiveness (OEE)

Overtime Maintenance Cost (5.5.7)
This metric is the cost of overtime maintenance labor used to maintain assets divided by the total cost of maintenance labor used to maintain assets, expressed as a percentage.
Used in 5.5.7 Overtime Maintenance Cost

Overtime Maintenance Hours (5.5.8)
This metric is the number of overtime maintenance labor hours used to maintain assets, divided by the total maintenance labor hours to maintain assets, expressed as a percentage.
Used in 5.5.8 Overtime Maintenance Hours

Overtime Maintenance Labor Cost (component)
The cost of any hours worked beyond the standard work period or shift (e.g., eight hours per day or 40 hours per week) multiplied by the labor rate. Includes production incentives, but not profit sharing. Includes labor costs for normal operating times as well as for outages, shutdowns or turnarounds. Also includes labor cost for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include labor cost used for capital expenditures for plant expansions or improvements. Typically, overtime labor cost does not include temporary contractor labor overtime cost.
Used in 5.5.7 Overtime Maintenance Cost

Overtime Maintenance Labor Hours (component)
Any hours beyond the normal standard work period or shift (e.g., eight hours per day or 40 hours per week). Include overtime maintenance labor hours for normal operating times as well as outages, shutdowns or turnarounds. If operator hours spent on maintenance activities are captured, they should be included in the numerator and denominator of all applicable metrics. Overtime maintenance labor hours include labor hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. It does not include labor hours used for capital expenditures for plant expansions or improvements. Typically, overtime maintenance labor hours does not include temporary contractor labor overtime hours.
Used in 5.5.8 Overtime Maintenance Cost

Percentage of Work Orders with Kitted Materials
The measure of the number of work orders for which required parts have been identified, secured (pick listed), packaged and available to do the job divided by all work orders x 100.
Used in BM Survey

Performance Efficiency (Rate/Speed)
The degree to which the equipment operates at historical best speeds, rates and/or cycle times.
Used in 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 Total Effective Equipment Performance (TEEP)

Performance Trending
The process of assessing progress toward achieving predetermined goals, including information on the efficiency with which resources transformed into goods and services, outputs, the quality of those outputs, how well they are delivered to the customers and the extent to which customers are satisfied.
Used in BM Survey

Personal Time
The time when a worker is taking care of personal business (e.g., making or receiving a personal phone call, meeting with Human Resources or a union steward, using the restroom and other similar personal activities).
Used in 5.6.1 Wrench Time

Planned Backlog (5.4.8)
This metric is the combination of the quantity of work that has been fully planned for execution, but is not ready to be scheduled and work that is ready to be performed. Also known as ready work.
Used in 5.4.8 Planned Backlog

Planned Cost
The planner's estimate of cost to complete the work order. Contingencies should not be included.
Used in 5.3.3 Actual Cost to Planning Estimate, 5.3.5 Planning Variance Index

Planned Interval Hours
The number of planned operating hours on a piece of equipment between scheduled preventive maintenance (PM) or predictive maintenance (PdM) events.
Used in 5.4.11 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Orders Overdue

Planned Labor Hours
The planner's estimate of the labor hours required to complete a work order.
Used in 5.3.6 Planner Productivity

Planned Preventive Maintenance (PM) & Predictive Maintenance (PdM) Frequency
Planned frequency or cycle over which a given preventive maintenance (PM) or predictive maintenance (PdM) task is to be repeated, measured in hours, day or months.
Used in 5.4.10 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Order Compliance

Planned Work (5.3.1)
This metric is the amount of planned maintenance work that was completed versus the total maintenance labor hours, expressed as a percentage. Planning adds value for the craft worker through preparation and an understanding of work request prior to the commencement of work. Maintenance planning is a highly skilled function that requires a basic knowledge of the maintenance work process, operations, project management, maintenance management system (MMS) and related systems, as well as a practical understanding of the work to be performed. Planning is the "what's required" and "how to" part of any maintenance job.
Used in 5.3.1 Planned Work

Planned Work (component)
Work that has gone through a formal planning process to identify labor, materials, tools, and safety requirements. This information is assembled into a job plan package and communicated to craft workers prior to the start of the work.
Used in 5.3.6 Planner Productivity, 5.4.8 Planned Backlog, 5.5.2 Craft Worker to Planner Ratio, Guideline 5.0

Planned Work Executed
Labor hours for work that were formally planned and completed.
Used in 5.3.1 Planned Work, 5.3.5 Planning Variance Index

Planned Work Order Hours
The planner's estimate of hours needed to complete the work order.
Used in 5.3.4 Actual Hours to Planning Estimate

Planner
A formally trained maintenance professional who identifies labor, materials, tools and safety requirements for maintenance work orders. The planner assembles this information into a job

plan package and communicates it to the maintenance supervisor and/or craft workers prior to the start of the work.
Used in 5.3.6 Planner Productivity, 5.5.2 Craft Worker to Planner Ratio

Planner Productivity (5.3.6)
This metric measures the average amount of planned work a maintenance planner prepares per month. This metric can be calculated as the number of planned labor hours, number of job plans or the number of planned work orders per month.
Used in 5.3.6 Planner Productivity

Planning Time
The time when a maintenance craft worker is planning a job. Includes planning emergency and unscheduled work, including scope creep.
Used in 5.6.1 Wrench Time

Planning Variance Index (5.3.5)
This metric measures the percentage of planned work orders closed in which the actual cost varied within +/- 20% of the planned cost.
Used in 5.3.5 Planning Variance Index

Point Availability (A_t)
A_t is the probability that a device, system or component will be operational at any random point in time. It is also called instantaneous availability and is expressed by the formula:

$$A_t = R(t) + \int_0^t R(t-u)m(u)du$$

Where R(t) = Probability of operating during time (t)
m(u) = The renewal density function
And u = The last repair time (0 < u < t)
Used in Guideline 6.0

Predictive Maintenance (PdM)
An equipment maintenance strategy based on assessing the condition of an asset to determine the likelihood of failure and then taking appropriate action to avoid failure. The condition of equipment can be measured using condition monitoring technologies, statistical process control, equipment performance indicators or through the use of human senses.
Used in 5.4.2 Proactive Work, 5.4.12 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Yield, 5.4.13 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Effectiveness

Preventive Maintenance (PM)
Actions performed on a time- or machine-run-based schedule that detect, preclude or mitigate degradation of a component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level.
Used in 5.1.3 Preventive Maintenance Cost, 5.1.4 Preventive Maintenance Hours, 5.4.2 Proactive Work, 5.4.12 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Yield, 5.4.13 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Effectiveness

Preventive Maintenance Cost (5.1.3)
This metric is the maintenance cost that is used to perform fixed interval maintenance tasks, regardless of the equipment condition at the time. The result is expressed as a percentage of total maintenance costs.
Used in 5.1.3 Preventive Maintenance Cost

Preventive Maintenance Cost (component)
The labor, material and services cost, including maintenance performed by operators (e.g., total productive maintenance (TPM), by company personnel or contractors for work performed as preventive maintenance. Includes operator costs if all operator maintenance costs are included in total maintenance cost.
Used in 5.1.3 Preventive Maintenance Cost

Preventive Maintenance Hours (5.1.4)
This metric is the percentage of maintenance labor hours used to perform fixed interval maintenance tasks, regardless of the equipment condition at the time.
Used in 5.1.4 Preventive Maintenance Hours

Preventive Maintenance Hours (component)
The maintenance labor hours to replace or restore an asset at a fixed interval regardless of its condition. Scheduled restoration and replacement tasks are examples of preventive maintenance.
Used in 5.1.4 Preventive Maintenance Hours

Preventive Maintenance Labor Hours (component)
The maintenance labor hours to replace or restore an asset at a fixed interval regardless of its condition. Scheduled restoration and replacement tasks are examples of preventive maintenance.
Used in 5.1.4 Preventive Maintenance Hours

Preventive Maintenance (PM) & Predictive Maintenance (PdM) Compliance (5.4.14)
This metric is a review of completed preventive maintenance (PM) and predictive maintenance (PdM) work orders, wherein the evaluation is against preset criteria for executing and completing the work.
Used in 5.4.14 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Compliance

Preventive Maintenance (PM) & Predictive Maintenance (PdM) Corrective Work Orders
All corrective work orders that are generated from a preventive maintenance (PM) or predictive maintenance (PdM) inspection or task.
Used in 5.4.13 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Effectiveness

Preventive Maintenance (PM) & Predictive Maintenance (PdM) Effectiveness (5.4.13)
This metric is a measure of the effectiveness of the corrective work that results directly from preventive maintenance (PM) and predictive maintenance (PdM) strategies. The measure is the amount of corrective work identified from PM/PdM work orders that was truly necessary.
Used in 5.4.13 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Effectiveness

Preventive Maintenance (PM) & Predictive Maintenance (PdM) Frequency
Cyclical period of a specific unit of measure in which preventive maintenance (PM) and predictive maintenance (PdM) activities are repeated.
Used in 5.4.10 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Order Compliance

Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Order Compliance (5.4.10)
This metric measures the percentage of preventive maintenance (PM) and predictive maintenance (PdM) work orders that were completed past the expected date (e.g., overdue) for a given completion date range. The overdue variance is calculated for each work order. It is recommended that results are grouped in ranges of overdue variance (%) and by criticality rank.
Used in 5.4.10 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Order Compliance

Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Orders Overdue (5.4.11)
This metric measures all active preventive maintenance (PM) and predictive maintenance (PdM) work orders (e.g., ongoing, not closed) in the system not completed by due date.
Used in 5.4.11 PM & PdM Work Orders Overdue

Preventive Maintenance (PM) & Predictive Maintenance (PdM) Yield (5.4.12)
This metric measures the volume of corrective work that results directly from preventive maintenance (PM) and predictive maintenance (PdM) work orders. The amount of repair and replacement work that is identified when performing PM or PdM work compared to the amount of PM or PdM work being done.
Used in 5.4.12 PM & PdM Yield

Proactive Work (5.4.2)
This metric is maintenance work that is completed to avoid failures or to identify defects that could lead to failures. Includes routine preventive and predictive maintenance activities and corrective work tasks identified from them.
Used in 5.4.2 Proactive Work

Proactive Work (component)
Maintenance work that is completed to avoid failures or to identify defects that could lead to failures. It includes routine preventive and predictive maintenance activities and work tasks identified from them.
Used in Guideline 5.0

Production Planner
The person responsible for determining production details and timelines.
Used in BM Survey

Quality
The percentage of "first pass, first time" saleable production to the actual production.
Used in Guideline 2.0

Quality Rate
The degree to which product characteristics meet the product or output specifications.
Used in 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 Total Effective Equipment Performance (TEEP)

Ratio of Replacement Asset Value to Craft-Wage Headcount (1.1)
This metric is the replacement asset value (RAV) of the assets being maintained at the plant divided by the craft-wage employee headcount. The result is expressed as a ratio in dollars per craft-wage employee.
Used in 1.1 Ratio of Replacement Asset Value to Craft–Wage Headcount

Reactive Work (5.4.1)
This metric is maintenance work that interrupts the weekly schedule, calculated as a percentage of the total maintenance labor hours.
Used in 5.4.1 Reactive Work

Reactive Work (component)
Maintenance work that breaks into the weekly schedule.
Used in Guideline 5.0

Ready Backlog (5.4.9)
This metric is the quantity of work that has been fully prepared for execution, but has not yet been executed. It is work for which all planning has been done and materials procured, but is waiting to be scheduled for execution.
Used in 5.4.9 Ready Backlog

Ready Work
Work that has been prepared for execution (e.g., necessary planning has been done, materials procured and labor requirements have been estimated).
Used in 5.4.8 Planned Backlog, 5.4.9 Ready Backlog

Reliability Analysis
A technique (with predictive tools) used to estimate the "life" of an asset (product). Usually expressed in terms of hours as mean time between failures (MTBF). Reliability analysis of system/assets ensures delivery of good products or services. Analysis helps to identify and to avoid some catastrophic events due to failure of component(s).
Used in BM Survey

Reliability Information Systems
Systems that take data collected by a maintenance management system (MMS) and apply reliability algorithms for the purpose of identifying opportunities to improve reliability in the company’s manufacturing systems/assets.
Used in BM Survey

Repair/Replacement Event
The act of restoring the function of an asset after failure or imminent failure by repairing or replacing the asset.
Used in 3.5.2 Mean Time to Repair (MTTR)

Repair/Replacement Time
The time required to restore the function of an asset after failure by repairing or replacing the asset. The duration of the repair or replacement begins when the asset ceases to operate to the time operability is restored. Includes time for checking the asset for its functionality prior to handing it over to operations.
Used in 3.5.2 Mean Time to Repair (MTTR)

Replacement Asset Value (RAV) (component)
Also referred to as estimated replacement value (ERV), it is the dollar value that would be required to replace the production capability of the present assets in the plant. Includes production/process equipment as well as utilities, facilities and related assets. Also includes the replacement value of buildings and grounds if these assets are included in maintenance expenditures. Does not include the insured value or depreciated value of the assets, nor does it include the value of real estate, only improvements.
Used in 1.1 Ratio of Replacement Asset Value (RAV) to Craft-Wage Headcount, 1.4 Stocked Maintenance, Reliability and Operating Materials (MRO) Inventory Value as a Percentage of Replacement Asset Value (RAV), 1.5 Annual Maintenance Cost as a Percentage of Replacement Asset Value

Report Date Range
The selected calendar period in which work order completion occurs.
Used in 5.4.10 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Order Compliance, 5.4.14 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Compliance

Required Date
The date when the preventive maintenance (PM) or predictive maintenance (PdM) work is scheduled to be completed.
Used in 5.4.10 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Order Compliance, 5.4.14 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Compliance

Return on Net Assets (RONA)
Calculates how well a company converts assets to sales and then to income. The simple calculation is sales minus expenses divided by net assets.
Used in BM Survey

Rework (4.1)
This metric is corrective work done on previously maintained equipment that has prematurely failed due to maintenance, operations or material problems. The typical causes of rework are maintenance, operational or material quality issues.
Used in 4.1 Rework

Root Cause Failure Analysis (RCFA)
An analysis used to determine the underlying cause or causes of a failure so that steps can be taken to manage those causes and avoid future occurrences of the failure.
Used in BM Survey, SMRP Guideline 4.0 – Guide to Mean Metrics

Schedule Compliance
The ratio of the actual number of work orders completed each week divided by the total number of work orders that were on the weekly schedule.
Used in BM Survey

Schedule Compliance – Hours (5.4.3)
This metric is a measure of adherence to the maintenance schedule, expressed as a percent of total time available to schedule.
Used in 5.4.3 Schedule Compliance - Hours

Schedule Compliance – Work Orders (5.4.4)
This metric is a measure of adherence to the weekly maintenance work schedule, expressed as a percent of total number of scheduled work orders.
Used in 5.4.4 Schedule Compliance – Work Orders

Scheduled Downtime (3.3)
This metric is the amount of time an asset is not capable of running due to scheduled work, (e.g., work that is on the finalized weekly schedule).
Used in 3.3 Scheduled Downtime, 3.5.4 Mean Downtime (MDT)

Scheduled Downtime (Hours) (component)
The time required to work on an asset that is on the finalized weekly maintenance schedule.
Used in 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 Total Effective Equipment Performance (TEEP), 2.2 Availability, 3.2 Total Downtime, 3.3 Scheduled Downtime, 3.5.4 Mean Downtime (MDT)

Scheduled Hours of Production
The amount of time an asset is scheduled to run (e.g., total available time, less idle time and less scheduled downtime).
Used in 2.1.1 Overall Equipment Effectiveness, 2.1.2 Total Effective Equipment Performance (TEEP)

Scheduled Work Performed (Hours)
The actual hours worked on scheduled work per the maintenance schedule.
Used in 5.4.3 Schedule Compliance – Hours

Self-directed Work Teams
Self-organized, semi-autonomous small groups whose members determine, plan and manage their day-to-day activities and duties in addition to providing other supportive functions, such as production scheduling, quality assurance and performance appraisal, under reduced or no supervision. Also called self-directed team, self-managed natural work team or self-managed team.
Used in BM Survey

Six Sigma
A set of practices designed to improve manufacturing processes and eliminate anything that could lead to customer dissatisfaction. Six sigma has a clear focus on achieving measureable and quantifiable returns on each executed project.
Used in BM Survey

Sound Monitoring (Audible)
The use of instruments or the human ear to detect changes in loudness, pitch, tone or frequency that could indicate pending problems with the functioning of equipment. Personal noise dosimetry is recommended to ensure that noise exposure for the full-shift (typically 8-hours) is captured to compare results directly with the OSHA limits. The results of this survey will determine if actions are necessary to ensure compliance with the OSHA Standard (1910.95) and minimize the potential for noise induced hearing loss. The enrollment in a hearing conservation program (hearing conservation program (HCP) is required if results of testing indicate that employee exposures exceed the Action Level of 85 dBA. The use of hearing protection and the implementation of feasible engineering and administrative controls are also required if exposures exceed the Permissible Exposure Limit of 90dBA.
Used in BM Survey

Standard Units Produced
A typical quantity produced as output. The output has acceptable quality and consistent means to quantify. Examples include: gallons, liters, pounds, kilograms or other standard units of measures.
Used in 1.3 Maintenance Unit Cost

Standing Work Orders (5.4.5)
This metric is the ratio of the hours worked on standing work orders to the total maintenance labor hours, expressed as a percentage.
Used in 5.4.5 Standing Work Orders

Standing Work Order (component)
A work order opened for a specific period of time to capture labor and material costs for recurring or short duration maintenance work and for work that is not associated with a specific piece of equipment where tracking work history or formalizing individual work orders is not cost effective or practical. Examples include: shop housekeeping, meetings, training, etc. Standing work orders are also referred to as a blanket work orders.

In some cases involving specific equipment, a standing work order may be used if the time and cost associated with the work is insignificant and if there is no need to capture maintenance history (e.g., time required to perform a routine daily adjustment).
Used in 5.4.5 Standing Work Orders

Statistical Process Control
A method of monitoring, controlling and improving a process through statistical analysis. Its four basic steps include measuring the process, eliminating variances in the process to make it consistent, monitoring the process and improving the process to its best target value.
Used in BM Survey

Stock Item
An inventoried item that is physically stored in the storeroom, including consignment stock, and that the storeroom manages at a specified quantity.
Used in 5.5.35 Storeroom Transactions, 5.5.36 Storeroom Records

Stocked Maintenance, Repair and Operating Materials (MRO) Inventory Value
The current book value of maintenance, repair and operating (MRO) supplies in stock, including consignment and vendor-managed inventory. Stocked MRO inventory value includes the value of MRO materials in all storage locations including satellite and/or remote storeroom locations, whether or not that material is included in inventory asset accounts or an allocated portion of

pooled spares. Estimates the value of unofficial stores in the plant, even if they are not under the control of the storeroom or are not on the books. Includes estimated value for stocked material that may be in stock at zero value because of various computerized maintenance management systems (CMMS) and/or accounting idiosyncrasies, etc. Does not include raw material, finished goods, packaging materials and related materials.

The monetary cost of an individual storeroom item is calculated as: Monetary Cost of Individual Storeroom Item = Quantity on Hand × Individual Item Cost

The aggregated cost of all storeroom items is calculated as: ∑N (Quantity on Hand × Individual Item Cost)i.
Used in 1.4 Stocked Maintenance, Reliability and Operating Materials (MRO) Inventory Value as a Percentage of Replacement Asset Value (RAV), 5.5.32 Vendor Managed Inventory, 5.5.34 Inactive Stock change definition term and definition in this metric

Stocked Maintenance, Repair and Operating Materials (MRO) Inventory Value as a Percent of Replacement Asset Value (RAV) (1.4)
This metric is the value of maintenance, repair and operating materials (MRO) and spare parts stocked onsite to support maintenance, divided by the replacement asset value (RAV) of the assets being maintained at the plant, expressed as a percentage.
Used in 1.4 Stocked MRO Inventory Value as a Percent of Replacement Asset Value (RAV)

Stock Outs (5.5.33)
This metric is the measure of the frequency that a customer goes to the storeroom inventory system and cannot immediately obtain the part needed.
Used in 5.5.33 Stock Outs

Storeroom Clerk
Any employee who has responsibility for the day-to-day activities in the storeroom measured as a full time equivalent (FTE). May also be known by other titles, such as storekeeper, storeroom attendant, etc. Typical duties include, but are not limited to, the following: issuing parts; stocking and labeling parts; organizing inventories; shipping equipment and materials (e.g., vendor returns, repairable spares, etc.); picking, kitting, staging, delivering and related activities; counting inventory (e.g., cycle counting); housekeeping; receiving activities (e.g., opening boxes, checking packing slips, noting discrepancies, etc.); and performing stock equipment and material maintenance activities (e.g., rotating shafts, inspecting belts, etc.).
Used in 5.5.35 Storeroom Transactions, 5.5.36 Storeroom Records

Storeroom Records (5.5.36)
This metric is the ratio of the number of maintenance, repair and operating (MRO) inventory stock records as individual stock keeping units (SKU's) of all MRO stock and non-stock items, including active stock, inactive stock and critical spares, to the total number of storeroom clerks used to manage the inventory.
Used in 5.5.36 Storeroom Records

Storeroom Transactions (5.5.35)
This metric is the ratio of the total number of storeroom transactions to the total number of storeroom clerks used to manage the inventory for a specified time period.
Used in 5.5.35 Storeroom Transactions

Storeroom Transaction (component)
Any materials management activity that results in the physical handling of an inventory item (stock or non-stock) or direct purchased item or that results in the exchange of data with the storeroom inventory management system. Inventory transactions occur any time an item is 'touched' either physically or electronically (e.g., a pick list with ten items picked would equal ten transactions). Inventory transactions include: receiving, stocking, adding, picking, kitting, staging, issuing, delivering, returning, adjusting, counting inventory stock item, EOQ analysis, etc.
Used in 5.5.35 Storeroom Transactions

Stores Inventory Turns (5.5.31)
This metric is a measure of how quickly inventory is flowing through the storeroom inventory system. It can be applied to different categories of inventory, including spares and operating.
Used in 5.5.31 Stores Inventory Turns

Supervisor
A first-line leader who is responsible for work execution by craft workers.
Used in 5.5.1 Craft Worker to Supervisor Ratio

Supervisor to Craft Worker Ratio (5.5.1)
This metric is the ratio maintenance craft workers to supervisors.
Used in 5.5.1 Supervisor to Craft Worker Ratio

Systems
A set of interrelated or interacting elements. In the context of dependability, a system will have the following: (a) a defined purpose expressed in terms of required functions; (b) stated conditions of operation and (c) defined boundaries.
Used in 3.1 Systems Covered by Criticality Analysis, 5.4.10 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Work Order Compliance

Systems Covered by Criticality Analysis (3.1)
This metric is the ratio of the number of systems in a facility for which a criticality analysis has been performed divided by the total number of systems in the facility, expressed as a percentage.
Used in 3.1 Systems Covered by Criticality Analysis

Temperature Monitoring
A monitoring technique that looks for potential failures that cause a rise in the temperature of the equipment itself, as opposed to the material being processed. If related to electrical circuitry, temperature monitoring can protect electronic components from being subjected to high temperatures.
Used in BM Survey

Today's Date
The current work day.
Used in 5.4.6 Work Order Aging

Total Available Time
Annual Basis: 365 days/year x 24 hours/day = 8760 hours per year (Note: The addition of one more day per year must be made for leap year.) Daily Basis: 24 hours
Used in 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 Total Effective Equipment Performance (TEEP), 2.2. Availability, 2.3 Uptime, 2.4 Idle Time, 2.5 Utilization Time, 3.2 Total Downtime, 3.4 Unscheduled Downtime

Total Available Time to Schedule
The total number of craft hours available to schedule. It does not include vacation, illness or injury and other similar time off.
Used in 5.4.3 Schedule Compliance - Hours

Total Downtime (3.2)
This metric is the amount of time an asset is not capable of running. The sum of scheduled downtime and unscheduled downtime.
Used in 3.2 Total Downtime

Total Downtime (component)
The amount of time an asset is not capable of running. The sum of scheduled downtime and unscheduled downtime.
Used in 2.3 Uptime, 3.2 Total Downtime, 3.5.4 Mean Downtime (MDT)

Total Effective Equipment Performance (TEEP) (2.1.2)
This metric is the measure of equipment or asset performance based on actual utilization time, availability, performance efficiency and quality of product or output over all the hours in the period. Total effective equipment performance (TEEP) is expressed as a percentage.
Used in 2.1.2 Total Effective Equipment Performance (TEEP)

Total Internal Maintenance Employee Labor Cost
Includes all internal maintenance labor costs (including benefits), both straight time and overtime, for all direct and indirect maintenance employees. Includes maintenance labor costs for normal operating times, as well as outages/shutdowns/turnarounds. Also includes labor for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Includes the cost for maintenance work performed by operators. Does not include labor used for capital expenditures for plant expansions or improvements or contractor labor cost. Does not include janitorial cost or other similar costs not associated with the maintenance of plant equipment.
Used in 4.2.1 Maintenance Training Cost, 5.5.5 Internal Maintenance Employee Cost

Total Maintenance Cost
The total expenditures for maintenance labor, including maintenance performed by operators such as total productive maintenance (TPM), materials, contractors, services and resources. Includes all maintenance expenses for outages, shutdowns or turnarounds, as well as normal operating times. Also includes capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include capital expenditures for plant expansions or improvements.
Used in 1.3 Maintenance Unit Cost, 1.5 Annual Maintenance Cost as a Percentage of Replacement Asset Value (RAV), 5.1.1 Corrective Maintenance Cost, 5.1.3 Preventive Maintenance Cost, 5.1.5 Condition Based Maintenance Cost, 5.1.9 Maintenance Shutdown Cost, 5.5.4 Indirect Maintenance Personnel Cost, 5.5.5 Internal Maintenance Personnel Cost, 5.5.38 Maintenance Material Cost, 5.5.71 Contractor Cost

Total Maintenance Cost as a Percent of Replacement Asset Value (RAV) (1.5)
This metric is the amount of money spent annually maintaining assets, divided by the replacement asset value (RAV) of the assets being maintained, expressed as a percentage.
Used in 1.5 Total Maintenance Cost as a Percent of Replacement Asset Value (RAV)

Total Maintenance Employee Hours
All internal maintenance labor hours, both straight time and overtime. Internal maintenance personnel are plant employees only, not contractors. Includes hours for normal operating times, as well as outages, shutdowns or turnarounds. Includes hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Include the hours for staff overhead support (supervisors, planners, managers, storeroom personnel, etc.). Include the hours for maintenance work done by operators. Does not include hours used for capital expenditures for plant expansions or improvements.

Used in 5.7.1 Continuous Improvement Hours

Total Maintenance Employee Labor Costs
Maintenance employee costs, including all internal maintenance labor cost benefits (both straight time and overtime) for all direct and indirect maintenance employees. Include maintenance labor costs for normal operating times, as well as outages, shutdowns or turnarounds. Include labor for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked and the cost for maintenance work done by operators. Do not include labor used for capital expenditures for plant expansions or improvements, nor do they include contractor labor cost. Total maintenance employee labor costs also do not include janitorial cost or other similar costs not associated with the maintenance of plant equipment. Same as total internal maintenance employee labor cost.
Used in 4.2.1 Maintenance Training Cost

Total Maintenance Labor Cost
Expressed in dollars, including overtime. Total cost includes all maintenance labor hours multiplied by the labor rate, plus any production incentive, but not profit sharing. Includes maintenance labor costs for normal operating times, as well as outages, shutdowns or turnarounds. Includes labor for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include labor used for capital expenditures for plant expansions or improvements. Typically, does not include temporary contractor labor cost.
Used in 5.5.7 Overtime Maintenance Cost

Total Maintenance Labor Hours
Expressed in hours and includes all maintenance labor hours for normal operating times as well as outages, shutdowns and turnarounds. If operator hours spent on maintenance activities are captured, they should be included in the numerator and denominator of all applicable metrics. Include labor hours for capital expenditures directly related to end-of-life machinery replacement so that excessive replacement versus proper maintenance is not masked. Does not include labor hours used for capital expansions or improvements. Typically, total maintenance labor hours do not include temporary contractor labor hours.
Used in 4.1 Rework, 5.1.2 Corrective Maintenance Hours, 5.1.4 Preventive Maintenance Hours, 5.1.6 Condition Based Maintenance Hours, 5.3.1 Planned Work, 5.3.2 Unplanned Work, 5.4.1 Reactive Work, 5.4.2 Proactive Work, 5.4.5 Standing Work Orders, 5.5.8 Overtime Maintenance Hours, 5.5.72 Contractor Hours

Total Maintenance Training Cost
The sum of all costs for formal training that is directed at improving job skills for maintenance employees. Training cost should include all employee labor, travel expenses, materials, registration fees, instructor fees, etc.
Used in 4.2.1 Maintenance Training Costs, 4.2.3 Maintenance Training ROI

Total Number of Inventory Requests
The total of all requests for items listed as stocked in the storeroom inventory system.
Used in 5.5.33 Stock Outs

Total Number of Scheduled Work Orders
The total number of work orders on the weekly schedule.
Used in 5.4.4 Schedule Compliance – Work Orders

Total Reactive Work (Hours)
Maintenance labor hours that were not scheduled and breaks into the weekly schedule. This is usually emergency and unplanned work as a result of unscheduled downtime (SMRP Metric 3.4).
Used in 5.4.1 Reactive Work

Total Time Available to Schedule
The total number of craft hours available to schedule. It does not include vacation, illness or injury and other similar time off.
Used in 5.4.3 Schedule Compliance

Total Units Produced
The number of units produced during a designated time period.
Used in 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 Total Effective Equipment Performance (TEEP)

Total Work
See total maintenance labor hours.

Total Work Time
The total time that maintenance craft workers are being paid to accomplish work, commonly referred to as being "on the clock." This includes straight time and overtime, whether scheduled or unscheduled.
Used in 5.6.1 Wrench Time

Training
Instruction provided in a formal setting, and it will typically include classroom and hands-on training with testing to confirm comprehension. Examples of training are safety (LOTO, JSA, etc.), interpersonal skills development (leadership, ESL, supervisory, etc.), math skills, computer skills, use of CMMS, job planning, reliability (FMEA, RCFA, etc.), problem solving, blueprint reading, alignment, balancing, lubrication, welding, all certifications (CMRP, CMRT, vibration, thermography, ultrasound, etc.), pneumatics, hydraulics, fasteners, use of specialized tools, equipment specific training, etc. Attendance at conventions and seminars is also credited as training, as long as the subjects fall within the SMRP Body of Knowledge.
Used in 4.2.1 Maintenance Training Costs

Training Hours
All time spent on formal technical training that is designed to improve job skills. Training provided in a formal setting and typically includes classroom and hands-on training with testing to confirm comprehension. Training can include, but is not limited to, safety, leadership, technical, computer, planning, reliability, problem solving and similar topics. Attendance at conventions, seminars and workshops is credited as training, as long as the subjects fall within the SMRP Body of Knowledge.
Used in 4.2.2 Maintenance Training Hours

Training Time
The time when a maintenance craft worker is receiving formal or informal training. Can be in a classroom or on the job.
Used in 5.6.1 Wrench Time

Unloaded Travel Time
The time when a maintenance craft worker is traveling, regardless of the reason or the mode of transportation (e.g., not carrying materials or tools while walking, riding, etc.)
Used in 5.6.1 Wrench Time

Unplanned Work (5.3.2)
This metric is the amount of unplanned maintenance work (hours) that was completed versus the total maintenance labor hours, expressed as a percentage. Planning adds value for the craft worker through preparation and an understanding of work request prior to the commencement of work. Maintenance planning is a highly skilled function that requires a basic knowledge of the maintenance work process, operations, project management, maintenance management system (MMS) and related systems, as well as a practical understanding of the work to be performed. Planning is the "what's required" and "how to" part of any maintenance job. A high percentage of unplanned work is an indication of a reactive work environment and a lack of proper planning.
Used in 5.3.2 Unplanned Work

Unplanned Work (component)
Work that has not gone through a formal planning process.
Used in 5.3.2 Unplanned Work, Guideline 5.0

Unplanned Work Executed
Equal to labor hours for work in which all labor, materials, tools, safety considerations and coordination with the asset owner have not been estimated and communicated prior to the commencement of work.
Used in 5.3.2 Unplanned Work

Unscheduled Downtime (3.4)
This metric is the amount of time an asset is not capable of running due to unscheduled repairs (e.g., repairs not on the finalized weekly maintenance schedule).
Used in 3.4 Unscheduled Downtime

Unscheduled Downtime (component)
The time an asset is down for repairs or modifications that are not on the weekly maintenance schedule.
Used in 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 Total Effective Equipment Performance (TEEP), 2.2. Availability, 3.2 Total Downtime, 3.4 Unscheduled Downtime, 3.5.4 Mean Downtime (MDT)

Unscheduled Work
Work not on the weekly schedule.
Used in 2.2 Availability

Uptime (2.3)
This metric is the amount of time an asset is actively producing a product or providing a service. It is the actual running time.
Used in 2.3 Uptime

Uptime (component)
The amount of time an asset is actively producing a product or providing a service. It is the actual running time.
Used in 2.1.1 Overall Equipment Effectiveness (OEE), 2.1.2 Total Effective Equipment Performance (TEEP), 2.2 Availability, 2.3 Uptime

Utilization Time (2.5)
This metric measures the percent of total time that an asset is scheduled to operate during a given time period, expressed as a percentage. The time period is generally taken to be the total available time (e.g., one year).
Used in 2.5 Utilization Time

Utilization Time (component)
Time when the asset is scheduled to run divided by total available time, expressed as a percentage.
Used in 2.1.2 Total Effective Equipment Performance (TEEP), 2.5 Utilization Time

Ultrasonic Testing
A technique of locating defects in a material by passing acoustic energy in the ultrasound range through it. Can be used for pinpointing surface, as well as deep defects.
Used in BM Survey

Value of Stock on Hand
The current value of the stock in inventory.
Used in 5.5.31 Stores Inventory Turns

Value of Stock Purchased
The value of the inventory items purchased in the period for which the metric is being calculated.
Used in 5.5.31 Stores Inventory Turns

Vendor Managed Inventory (5.5.32)
This metric is the ratio of the number of stocked items measured as individual stock keeping units (SKUs) that are managed by a vendor or supplier to the total number of stocked items held in inventory.
Used in 5.5.32 Vendor Managed Inventory

Vendor Managed Inventory (component)
Stocked items measured as individual stock keeping units (SKUs) that are managed by a vendor or supplier.
Used in 5.5.32 Vendor Managed Inventory

Vibration Monitoring
A monitoring technique used to determine asset condition and potentially predict failure. Assets are monitored using instrumentation, such as vibration analysis equipment or the human senses.
Used in BM Survey

Waiting Time
The time when a maintenance craft worker is waiting, regardless of the reason.
Used in 5.6.1 Wrench Time

Weekly Schedule
The list of maintenance work to be done in the week. It is usually finalized three to four days before the start of the work week.
Used in 3.2 Total Downtime, 3.3 Scheduled Downtime, 3.4 Unscheduled Downtime, 5.4.1 Reactive Work, 5.4.4 Schedule Compliance – Work Orders

Work Distribution by Priority
The act of scheduling work based on priority. Priority is driven by asset criticality and defect severity.
Used in BM Survey

Work Order Aging (5.4.6)
This metric measures the age of active work orders by using the work order creation date and comparing it to today's date to calculate the work order age, expressed in number of days.
Used in 5.4.6 Work Order Aging

Work Order Completion Date
The date the work order was closed in the maintenance management system. This is considered the technical completion date and includes that all data is captured within the MMS, including work done, hours worked, parts used, etc.
Used in 5.4.7 Work Order Cycle Time

Work Order Creation Date
The date the work order was written and entered into the maintenance management system. This could also be called a work request or notification date, depending on the maintenance management system in use.
Used in 5.4.6 Work Order Aging, 5.4.7 Work Order Cycle Time

Work Order Cycle Time (5.4.7)
This metric is the time from the creation of a work order until it is closed in the maintenance management system (MMS).
Used in 5.4.7 Work Order Cycle Time

Work Orders Necessary
Work where a defect or a potential failure was identified and corrected as a result of preventive maintenance (PM) and predictive (PdM) inspections or tasks.
Used in 5.4.13 Preventive Maintenance (PM) & Predictive Maintenance (PdM) Effectiveness

Work Sampling
The process of making a statistically valid number of observations to determine the percentage of total work time workers spend on each activity.
Used in 5.6.1 Wrench Time

Work Types
Classifications of maintenance work according to the nature of work performed.
Used in Guideline 5.0

Wrench Time (5.6.1)
This metric is a measure of the time a maintenance craft worker spends applying physical effort or troubleshooting in the accomplishment of assigned work. The result is expressed as a percentage of total work time. Wrench time is measured through a process called work sampling.
Used in 5.6.1 Wrench Time

Wrench Time (component)
The time when a maintenance craft worker is applying physical effort or troubleshooting in the accomplishment of assigned work.
Used in 5.6.1 Wrench Time